Historical Review of Hamilton Harbour Fisheries.

John A. Holmes[1] and T.H. Whillans[2]

[1]Institute for Environmental Studies,
University of Toronto,
Toronto, Ontario. M5S 1A4

[2]Environmental and Resource Studies,
Trent University,
Peterborough, Ontario. K9J 7B8

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John A. Holmes

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T. H. Whillans

Environmental and Resource Studies
Trent University
Peterborough, Ontario
K9J 7B8

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ABSTRACT

Holmes, J. A. and T. H. Whillans. 1984. Historical review of Hamilton Harbour fisheries. Can. Tech. Rep. Fish. Aquat. Sci., 1257. i-x + 117 pp.

Historical relationships between the fisheries, habitat, exploitation and interspecific interactions are compared with present conditions to determine the feasibility of fisheries rehabilitation in Hamilton Harbour. Commercial catch records are analysed for changes in fishing effort and relative abundance of species. These changes are correlated with changes in aquatic macrophytes, plankton, benthic invertebrates, bathymetry, bottom materials, and recreational fishing.

Lake trout, whitefish, and herring have been extirpated from the harbour. It is probable that a substantial suitable deepwater habitat remains. However, this habitat is completely unavailable because of extremely poor water quality, in particular low levels of dissolved oxygen.

Extensive warmwater habitat has been lost. However, changes in the warmwater fish community have not been as dramatic. New habitat and improvements in the quality of remaining habitat would probably result in a substantial increase in warmwater fish populations in the harbour.

Based on current evidence, rehabilitation of the Hamilton Harbour fisheries would probably contribute to a revitalized whitefish and herring fishery in western Lake Ontario. It is unlikely that re-establishing lake trout in the harbour would have any direct effect on the western Lake Ontario fishery.

This study shows that fisheries rehabilitation is feasible in much of the harbour. It provides an historical data base for future management of Hamilton Harbour.

Key Words: Hamilton Harbour, Historical, Fisheries Rehabilitation, Habitat.

RESUME

Holmes, J. A. and T. H. Whillans. 1984. Historical review of Hamilton Harbour fisheries. Can. Tech. Rep. Fish. Aquat. Sci., 1257. i-x + 117 pp.

On compare les relations historiques entre les pêches, l'habitat, l'exploitation et les interactions interspécifiques avec les conditions actuelles pour déterminer s'il est faisable de remettre en état les pêches dans le port de Hamilton. On analyse les données sur les prises commerciales pour déceler des changements dans l'effort de pêche et dans l'abondance relative des différentes espèces. On établit des corrélations entre ces changements et certains facteurs tels les macrophytes aquatiques, le plancton, les invertébrés benthiques, les données bathymétriques, les matières constituant le fond et la pêche sportive.

Touladis, corégones et ciscos ont été pêchés dans les eaux du port. Il est probable qu'il reste un important habitat d'eau profonde approprié. Toutefois, cet habitat est entièrement inaccessible à cause de la très mauvaise qualité de l'eau, surtout des faibles concentrations d'oxygène dissous.

On a perdu un habitat d'eau chaude très étendu. Cependant, les changements dans la communauté des poissons d'eau chaude n'ont pas été aussi spectaculaires qu'on aurait pu le croire. Un nouvel habitat et une amélioration de la qualité de l'habitat qui reste entraîneraient probablement une augmentation substantielle des populations de poissons d'eau chaude dans le port.

A partir des indications actuelles, on peut croire que la remise en état des pêches du port de Hamilton aiderait probablement à revitaliser les pêches de corégones et de cisco dans le secteur ouest du lac Ontario.

Il est peu probable que le rétablissement du touladi dans le port aura un effet direct quelconque sur la pêche dans le secteur ouest du lac Ontario.

Cette étude démontre que la remise en état des pêches est réalisable dans une grande partie du port. Elle fournit une base de données historiques pour la gestion future du port de Hamilton.

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1. INTRODUCTION

This review is intended to provide an historical data base which will contribute to an assessment of the feasibility of rehabilitating the Hamilton Harbour fishery. Rehabilitation is a pragmatic mixture of measures aimed at establishing a stable ecosystem and recovering some of the features of the initial wild state which are perceived to be desirable (Francis et al. 1979).

The increasing environmental awareness of the 1960's focussed attention on the degraded state of Hamilton Harbour. A variety of metals, PCB's and other organic substances contaminated the sediments (MOE 1977; 1978). Effluents from four municipal sewage treatment plants caused heavy pollution and eutrophication, with the result that the deep water of the outer basin became anoxic during the summer months due to algal decomposition and the high oxygen demand of the sediments (MOE 1977; 1978).

Probably as a result of increased environmental awareness and the 1972 and 1978 Water Quality Agreements serious efforts have been made to reduce the chemical inputs and improve water quality (IJC 1972; 1978). Industrial wastewater contributions to the harbour were significantly reduced through the use of new treatment technology on specific waste streams. Within the last five years all four sewage treatment plants have doubled in capacity and significantly reduced their organic contributions to the harbour. Experimental aeration of the deep hypolimnetic water in the mid-1970's had an extremely localized effect (MOE 1977; 1978). The outcome of these activities has been a reversal in the deterioration of water quality in Hamilton Harbour.

> "Contaminated sediments are still a major concern, however water quality continues to improve and solutions can be found to dispose of contaminated sediments and increase oxygen levels in the deeper waters." (Can. Dept. Fish. Oceans 1983).

This improving trend suggests that it would be timely to explore the potential for rehabilitating the Hamilton Harbour fishery. Analysis of the fish community structure and ecology is one way to do this. It is, however, difficult to comprehend the ecology of a fish community without an understanding of its history (Whillans 1979).

This review will focus on the changes that have occurred in the status of the commercial and recreational fisheries from the earliest records to the present. Close attention is given to documenting and reconstructing the historical changes in structural habitat features (especially those which might influence spawning and nursery activities) and exploitation. Aquatic macrophytes, plankton and benthic invertebrates are examined within the limitations imposed by data availability. Changes in these factors are correlated with fish community transformations documented by Whillans (1977; 1979) and species abundance in order to identify the major contributing agents to the decline of the Hamilton Harbour fishery.

The major objective of this review is to compare the historical relationships between the fisheries, habitat, exploitation and interspecific interactions with present conditions and determine the feasibility of fisheries rehabilitation. Key issues to be raised include the quantity and quality of the remaining habitat and the potential impact of a rehabilitated Hamilton Harbour fishery on the fishery of western Lake Ontario.

1.1 THE STUDY AREA

Hamilton Harbour is situated at the western end of Lake Ontario and consists of a large deep water outer basin and an extensive shallow water marsh to the west called Cootes Paradise (Fig. 1). Inflow is received from several tributaries which drain a relatively small watershed of 500 km^2 (MOE 1977).

The outer basin which is protected from Lake Ontario by Hamilton Beach, has a mean depth of 13 m and a volume of 2.8×10^8 m^3 (MOE 1977). Inputs are received from several tributaries, two municipal sewage treatment plants and a number of industries including two major steel companies, located along the south shore. Extensive shoreline restructuring has occurred along the heavily industrialized south shore since 1909 (Ozanian 1957).

Cootes Paradise is the largest remaining marsh along the western Lake Ontario shoreline (Whillans 1982). Inputs from tributary streams and two municipal sewage treatment plants have heavily polluted the water and caused rapid eutrophication in the last 65 years (Bacchus 1974).

Western Lake Ontario from Bronte to Grimsby (Fig. 1) is included within the scope of this review because Hamilton Harbour may have played a supporting role in the fishery of this area by providing important spawning or nursery habitat.

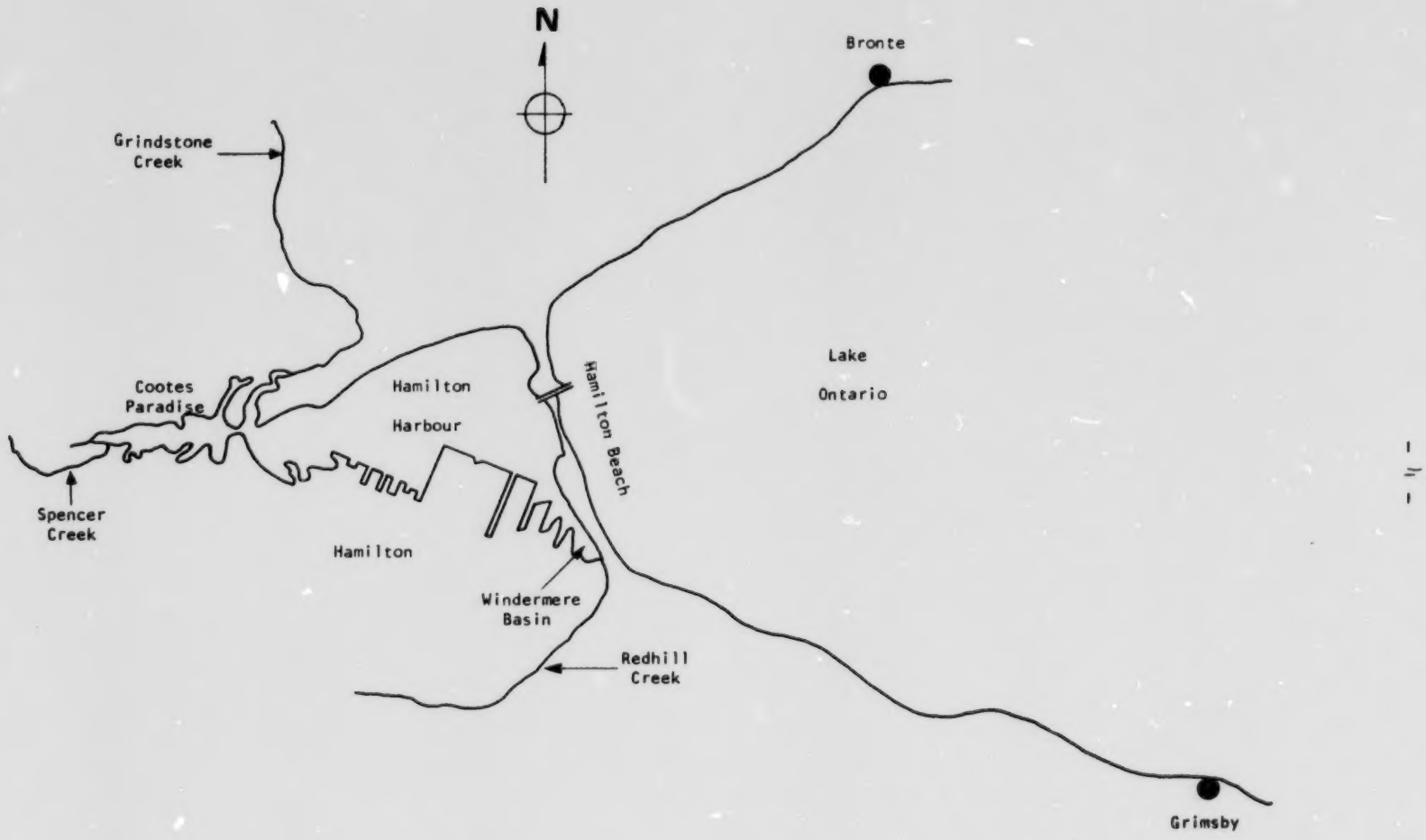


Fig. 1. Hamilton Harbour, the major tributaries and the surrounding study area.

1.2 INFORMATION SOURCES

Historical materials were researched over a four month period in the fall of 1983 at institutions across southern Ontario. These included the Public Archives of Canada (PAC), the Ontario Archives, the Ontario Ministry of Natural Resources (Queen's Park, Cambridge District Office, Glenora Fisheries Station), the Ontario Ministry of the Environment (Toronto), the Royal Botanical Gardens, the Hamilton Public Library and the libraries at the Universities of Toronto and Guelph and McMaster University.

Information came from two sources - traditional and non-traditional. Traditional fisheries sources include point-in-time habitat and species descriptions and inventories, time series data on fisheries and environmental parameters and formal publications interpreting these data (Whillans 1979).

Because traditional data is available only for limited periods within the last three or four decades the search was broadened to include non-traditional sources which are those not often used by fisheries scientists. These include old government files, the letters and diaries of fishery overseers, accounts in the popular press and the records of city council meetings.

Formal publications needed little verification. The reliability of non-traditonal data and some of the traditional data in the 1800's is difficult to ascertain. These sources were checked and scrutinized using methods suggested by Whillans (1977; 1979).

When sufficient series data existed they were analysed for changes in fishing effort and species abundance. When these data were deficient descriptive case histories were constructed. This was done for sport fishing, the distribution of selected species, habitat changes, aquatic macrophytes, benthic invertebrates and plankton.

2. COMMERICAL FISHING

2.1 SEQUENCE OF EVENTS

Commercial fishing with seines, began in the early 1820's at Hamilton Beach (Kerr, Feb. 10, 1894). Unhindered by regulations these operations flourished and grew. In 1859 John McCuaig, the fisheries superintendent for Upper Canada, laid out fishing stations on Hamilton Beach and attempted to regulate the use of seines (McCuaig, Dec. 31, 1859). Effective enforcement was not achieved until 1864 when John Kerr was appointed fishery overseer of the Hamilton Division (Kerr, Feb. 10, 1894).

Seines were widely used at Hamilton Beach through the 1860's but were gradually replaced by gill nets during the 1870's and 1880's. This had a noticeable effect on the fishery. By 1879 catches were so large that voluntary restrictions were placed on effort in order to avoid glutting the market (Kerr 1879).

Seines and gill nets were prohibited in Hamilton Harbour and Cootes Paradise except in the southeast corner of the harbour, because they were set aside for "the natural propagation of fish" (Kerr and Kerr, Feb. 3, 1865). In spite of numerous petitions in favour of commercial fishing (i.e. Kerr and Kerr, June 9, 1866; Jan. 1, 1868) only a small spring fishery in the southeast corner of the harbour was permitted. It began in 1869 (Kerr and Kerr, Feb. 6, 1869) and except for temporary bans in 1874 and 1894, seines have been fished in the harbour ever since.

By the late 1940's and early 1950's only two commercial fishermen were active in Cootes Paradise. In the 1950's the Royal Botanical Gardens did some trap netting and seining. Trap nets were fished again in 1973 and 1978. In the early 1960's one commercial fisherman ceased fishing and the other switched his activities to the waters west and north of Carroll's Point. Gill nets were set experimentally in the harbour in the mid 1970's by the Ministry of Natural Resources. The last remaining commercial fisherman stopped fishing after the 1977 season.

Gill nets have been used since the mid-1800's by commercial fishermen in western Lake Ontario. Commercial fishing was discontinued at Bronte after 1972. In the Grimsby area, there was a lull in activity between 1964 and 1973. Fishing resumed in 1973 although on a smaller scale than before.

2.2 ASSESSMENT OF THE COMMERICAL FISHERY

Changes in the status of the commercial fishery were assessed by comparing catch records for each species from 1871-1900 and 1948-1977. The 1871-1900 period is assumed to be representative of predegradation conditions in Hamilton Harbour. The 1871-1900 data were from the annual reports of the Canada Department of Marine and Fisheries (1871-1900). These reports are part of a continuous record of total catch and length of nets fished from 1867 to 1908. The 1948-1977 catch statistics were taken from the CF-1 records kept by the commercial fishermen and turned in monthly to the Ontario Ministry of Natural Resources. These records provide detailed information by area on daily and monthly catches and the lengths and types of nets fished by each fisherman.

The study area was divided into 5 sections - Cootes Paradise, Hamilton Harbour, Hamilton Beach, Bronte and Grimsby (Fig. 1). The 1948-1977 data were easily disaggregated by area. However, data from 1871-1900 presented a problem. Catches from Cootes Paradise were generally included with Hamilton Harbour and in some years (1877-1878 and 1883-1885) they were combined with catches at the beach. After 1885 catches were reported for Hamilton Beach only. In the Bronte and Grimsby sections catch data from the 1890's were not used because the reporting areas were changed making separation impossible.

Cach-per-unit-effort (CPUE) was calculated for the 1948-1977 data. Hile's (1962) definitions of fishing effort were used with slight modifications. For gill nets one unit of effort is one lift of 1000 linear yards of net. A unit of effort for seines is one haul of a 100 yard seine. CPUE was calculated only for gill nets in western Lake Ontario and seines in Hamilton Harbour.

An estimate of effort for the 1871-1900 data was obtained using the total yardage of nets fished per year. However, a particular species would not be fished with the total netting available in a given year nor is net length the only variable in effort. Caution is thus needed in interpreting these data.

Five year averages of catch and CPUE were plotted to determine relative abundance of species. Species abundance is recorded on a relative basis because absolute numbers are difficult to estimate given the nature of the source material and the investigative technique employed (Whillans 1977).

2.2.1 COLD WATER SPECIES

The cold water fish are the most valuable species in the commercial fishery and were the first to respond to stress. The species discussed in this section all showed signs of stress well before the turn of the 19th century in Hamilton Harbour. Species which inhabit the open waters of the harbour will be discussed first. Next in order are those species which spawn near shore but inhabit the thermocline in Lake Ontario (Christie 1973). This includes the lake herring and deepwater ciscoes although the latter should be in the first group. They are included in the second group because lake herring and cisco catches were rarely separated. Finally, migratory species which only use the harbour or its tributary streams for a critical period in their life history, will be briefly examined.

Chinook and coho salmon have been stocked in Lake Ontario since 1969 (Bridger and Oster 1981). These species are only recent entrants into the commercial fishery of western Lake Ontario (within the scope of this review) and do not figure prominently in catches at this time. They will be discussed along with other miscellaneous taxa at the end of this section.

Lake Trout Salvelinus namaycush

Hamilton Beach and Hamilton Harbour

Commercial catches of S. namaycush were low during the 1870's and 1880's (Fig. 2) due partly to competition from Georgian Bay fishermen for local and Toronto markets and partly to poor weather during some of the fishing seasons (Kerr 1876; 1877; 1880). This resulted in effort being

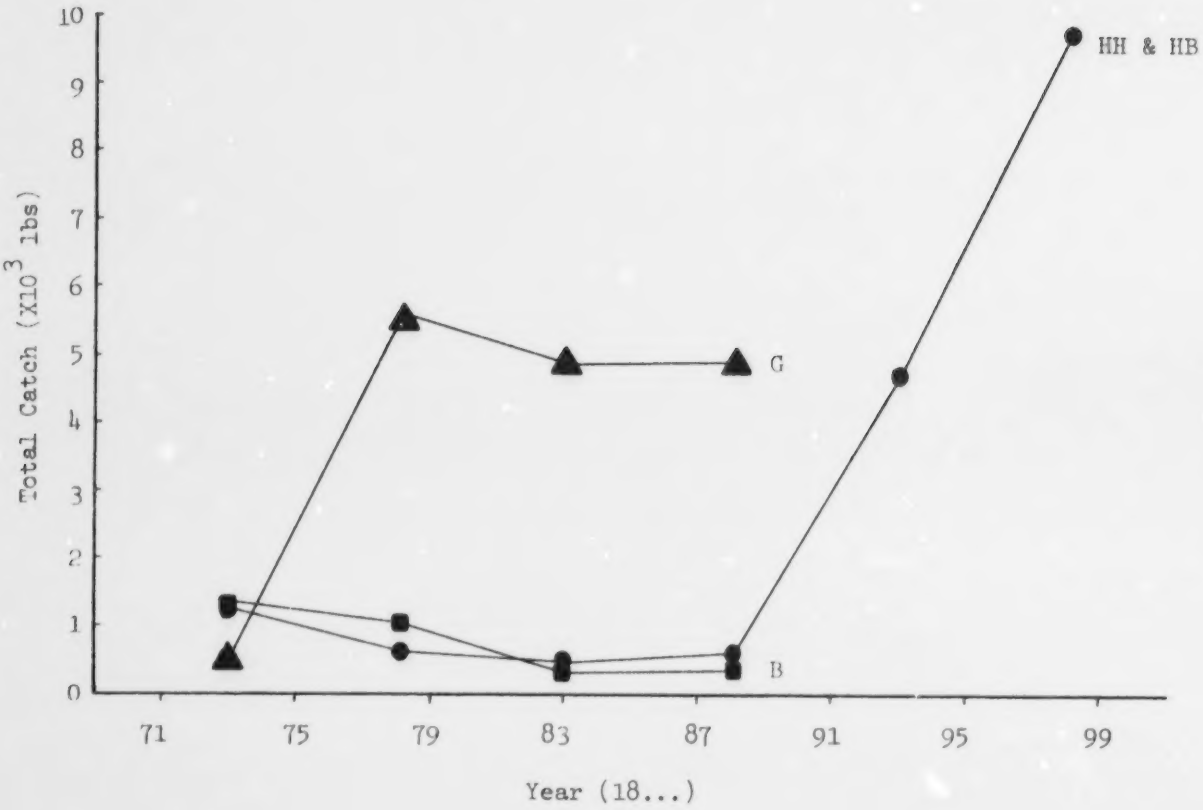


Fig. 2. Trends in the catch of Salvelinus namaycush in western Lake Ontario, 1871-1900. B-Bronte; G-Grimsby; HB-Hamilton Beach; HH-Hamilton Harbour.

switched to Coregonus artedii and C. clupeaformis. The increase in S. namaycush during the 1890's is puzzling (Fig. 2). A comparison with gill net effort which also increased during this period (Fig. 3) indicates that lake trout abundance was probably increasing. A similar increase was also noticed by commercial fishermen in the Toronto area (Hicks, Nov. 22, 1897). This increased abundance must have been small in magnitude and localized to the extreme western end of Lake Ontario because numerous authors, for example Christie (1973), have indicated that S. namaycush stocks were very low at the turn of the century. Why it occurred is unknown.

Salvelinus namaycush became non-existent in Hamilton Harbour by the mid-1930's (Whillans 1977). Commercial fishing records beginning in the late 1940's confirm this fact. Only occasional catches were made at the beach and the last of these was in 1959 (Table 1). Whillans (1977) reported that a small stock may still exist off of the beach. This is unlikely. Commercial fishing was of sufficient intensity through the 1960's that any remaining stock would probably have been caught.

Bronte and Grimsby

Salvelinus namaycush catches at Bronte show a slightly decreasing trend during the 1870's and 1880's but are similar in magnitude to catches in Hamilton Harbour and at the beach (Fig. 2). During this period effort increased substantially (Fig. 3). These data reflect the effects of competition from Georgian Bay fishermen more clearly than the harbour and beach data. Effort at Bronte switched to other species, primarily Coregonus artedii.

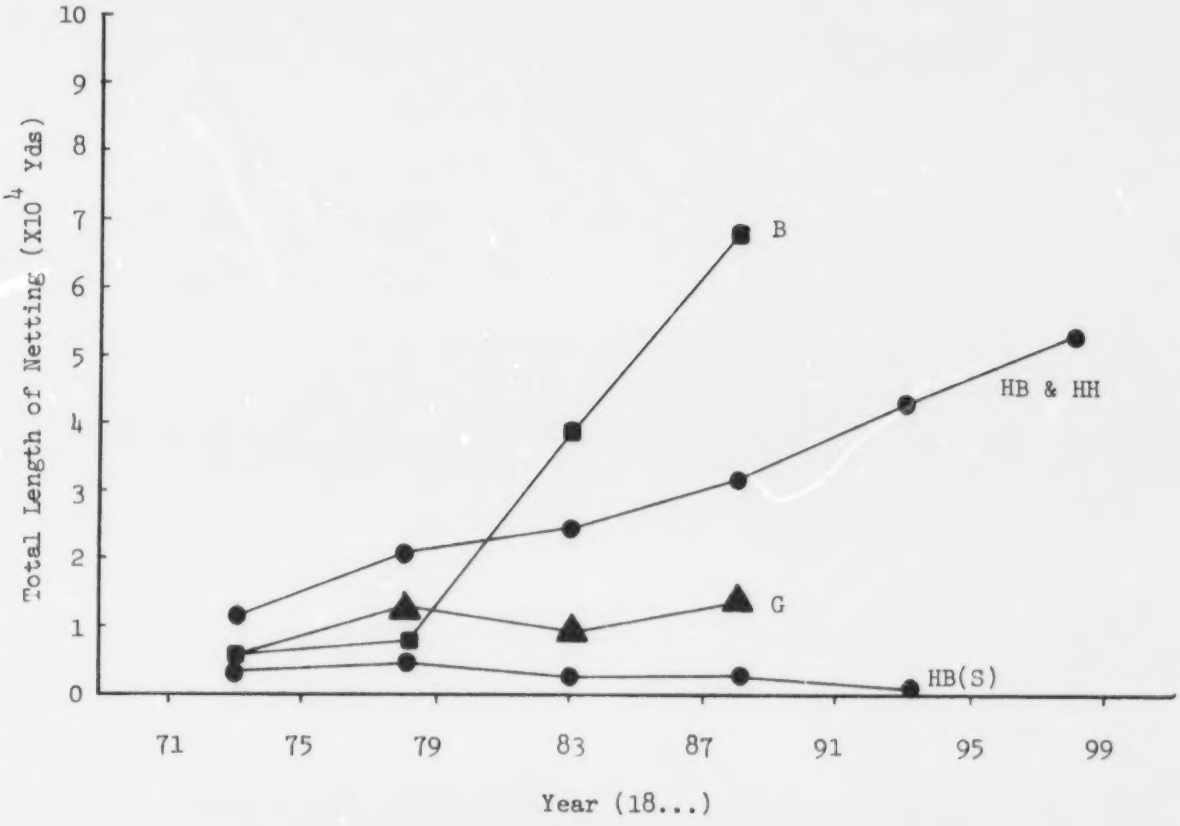


Fig. 3. Trends in the total length of gill nets fished in western Lake Ontario, 1871-1900. B-Bronte; G-Grimsby; HB-Hamilton Beach; HH-Hamilton Harbour; HB(S)-Hamilton Beach (seine).

Catches of S. namaycush at Grimsby were much higher than elsewhere during the 1870's and 1880's (Fig. 2). The slight increase in effort (Fig.3) indicates that abundance may have been increasing. The major reason for the large catches at Grimsby was the lack of competition from Georgian Bay fishermen who were supplying different markets.

Lake trout stocks collapsed in the 1940's (Christie 1973). A brief revival in catch occurred at Bronte and Grimsby in the early 1950's but by 1960 only stray catches were made (Table 1). The switch from cotton and linen to monofilament gill nets in 1950 (Christie 1973) was the likely source of the brief resurgence.

Discussion of Salvelinus namaycush

Historically the commercial fishery for S. namaycush was of more importance in western Lake Ontario even though a permanent stock existed in the harbour. Over-exploitation was a major factor in the decline of lake trout in Hamilton Harbour. Salvelinus namaycush annually migrated through the Burlington ship canal into Lake Ontario to spawn. This migration made lake trout extremely vulnerable to a strong seine fishery (Whillans 1977).

Additional stress imposed by the removal of spawning shoals in western Lake Ontario for building materials (Whillans 1977) and increasing domestic and industrial pollution in the harbour during the 1880's (Kerr and Kerr 1860-1898) probably contributed to the demise of S. namaycush as well.

The available evidence indicates that S. namaycush did not spawn in Hamilton Harbour. Instead, four well known shoals in western Lake Ontario between Clarkson and Whitby were probably utilized (Whillans 1977).

The lack of historic spawning shoals in the harbour and the uncertainty concerning whether the S. namaycush in the harbour were from a separate stock or a population of a larger stock in western Lake Ontario suggests that re-establishment of S. namaycush in the harbour would require lake-wide measures.

Locally within the harbour, the availability of S. namaycush habitat is limited by anoxic conditions which develop after stratification. Within western Lake Ontario there is no current evidence of spawning shoals and nursery areas.

Deepwater ciscoes Coregonus sp. and Lake Herring Coregonus artedii

These species are discussed together because it is extremely difficult to distinguish between members of the deepwater cisco complex (C. johannae, C. alpenae, C. reighardi, C. kiyi and C. hoyi) and C. artedii (Scott and Crossman 1973). Most of the early observations refer to C. artedii although Coregonus sp. could be included as well. Herring will be used throughout this section.

Early records and observations indicate the existence of two herrings - a larger blueback herring and a smaller common herring (Kerr and Kerr 1860-1898). They were not distinguished by Scott and Crossman (1973).

Hamilton Beach and Hamilton Harbour

The available data indicate that herring were extremely abundant in the harbour and at the beach particularly during the 1880's (Fig. 4). In the late 1880's catches were large probably because competition for lake trout markets forced many fishermen in western Lake Ontario to switch to the abundant stocks of herring (Fig. 3).

The catch data is consistent with observations made by Whillans (1977) who noted declines in herring abundance in the harbour and at the beach during the early 1870's and 1890's followed by a dramatic recovery by the turn of the century. Over-fishing is cited by Kerr and Kerr (1860-1898) as the primary cause of the declines.

Herring stocks declined precipitously after the turn of the century and by the late 1940's catches were two orders of magnitude less than historically (Fig. 5). The catch and CPUE data at the beach indicate abundance was low and declining and that a switch was made to other species. The CF-1 records show that most of the fishermen at the beach switched from large mesh to small mesh gillnets in the 1960's. A small stock may still exist off the beach (Whillans 1977).

Bronte and Grimsby

Catches of herring in western Lake Ontario indicate that herring abundance was increasing until the turn of the century (Fig. 4). Other reports, for example Christie (1973), observed the same event.

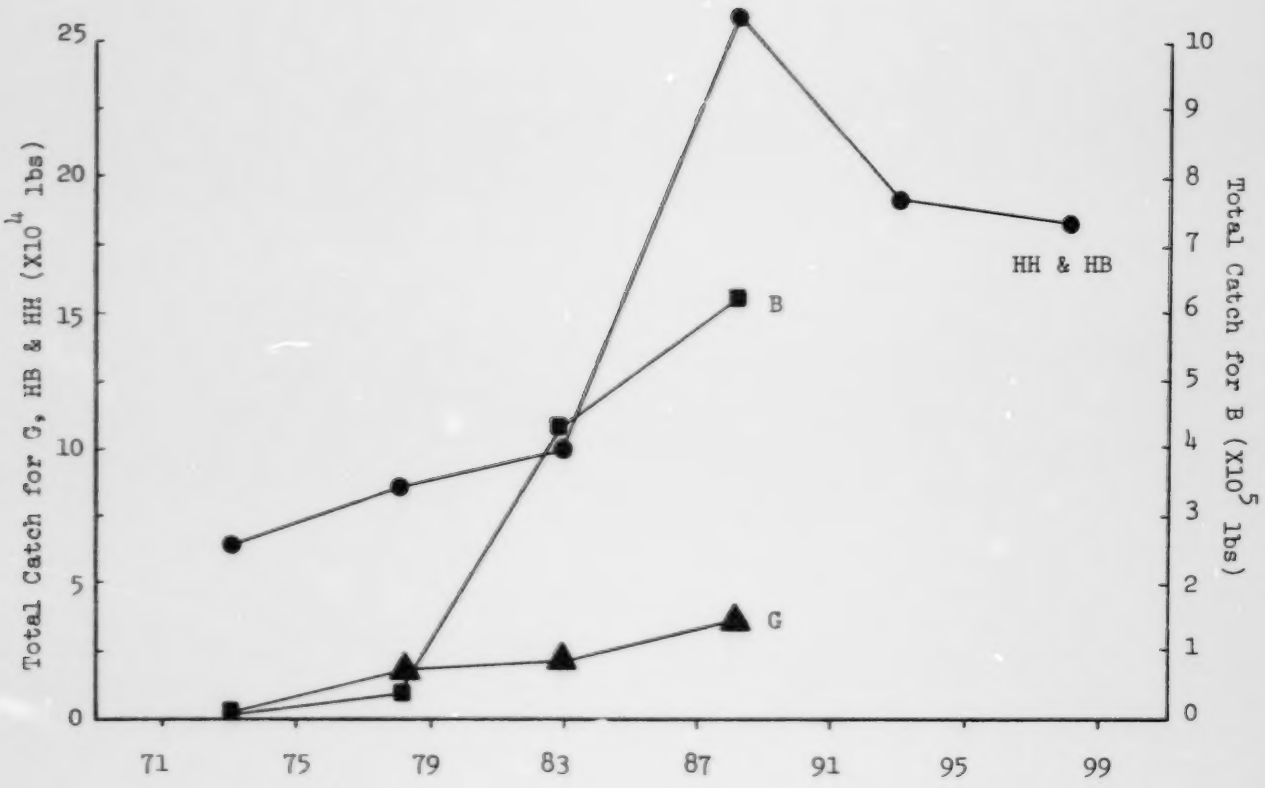


Fig. 4. Trends in the catch of Coregonus artedii and Coregonus sp. in western Lake Ontario, 1871-1900. B-Bronte; G-Grimsby; HB-Hamilton Beach; HH-Hamilton Harbour.

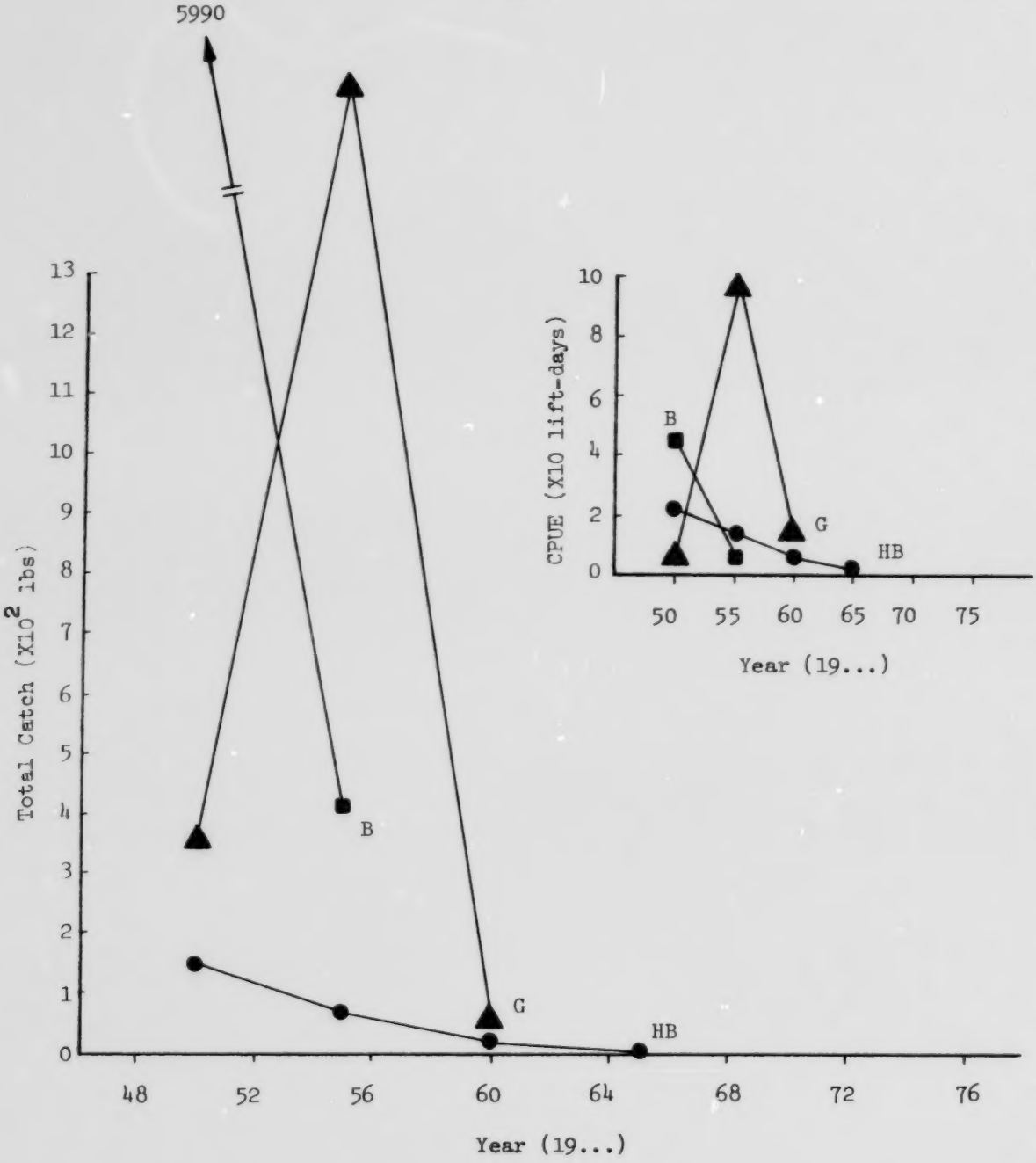


Fig. 5. Trends in the catch and CPUE of Coregonus artedii and Coregonus sp. in western Lake Ontario, 1948-1977. B-Bronte; G-Grimsby; HB-Hamilton Beach.

Historically, catches at Bronte were an order of magnitude greater than elsewhere (Fig. 4). Intense competition to supply other species probably caused many of the fishermen at Bronte to switch to herring in the late 1800's.

A substantial decline in abundance and catches occurred after the turn of the century. In the early 1950's a small peak occurred at both Bronte and Grimsby (Fig. 5). This probably was a result of the introduction of monofilament gillnets at this time. Herring stocks collapsed by the late 1950's (Christie 1973).

The timing of the peak catch and CPUE at Bronte and Grimsby suggests some fishermen from Bronte may have fished in the Grimsby section. The CF-1 records show that only one fisherman from Bronte moved to the Grimsby section and he did not catch any herring.

Discussion of Coregonus artedii and Coregonus sp.

Hamilton Harbour was one of the best herring habitats in the Great Lakes (Whillans 1977). A substantial number were permanent residents. In addition, millions more migrated into the harbour from western Lake Ontario to spawn in November (Kerr and Kerr, Sept. 5, 1868). A second smaller feeding immigration occurred in June and July.

Low predator abundance (i.e. S. namaycush) may explain the increased herring abundance around the turn of the century (Christie 1973). Strong

year classes due to "optimum temperatures for reproductive success" particularly in 1894 and 1898 may be another reason (Whillans 1977).

Over-exploitation and deteriorating water quality in the harbour after the turn of the century were major factors in the decline of herring in western Lake Ontario. Predation and competition for food resources from Alosa pseudoharengus and later Osmerus mordax cannot be ruled out. These species have been implicated as important factors in the local reduction or extinction of Lake Michigan herring (Stewart et al. 1981). Alewife has been a dominant species in the harbour since 1877 (Kerr and Kerr, Aug. 29, 1879).

Christie (1973) hypothesized that the abrupt collapse of Coregonus sp. and C. artedii in western Lake Ontario did not involve all the species in the cisco complex. Different species failed at different times. Catches of chubs and tullibees (deepwater ciscoes plus C. nigripinnis and C. zenithicus) at Bronte and Grimsby during the early 1950's may provide some support for this hypothesis.

Hamilton Harbour was an important habitat for permanent and migratory populations of herring in western Lake Ontario. Herring are presently limited from much of the deepwater habitat primarily because of anoxic conditions which develop after stratification. It is probable that re-establishment of a local herring population would have important effects on the western Lake Ontario fishery.

Whitefish Coregonus clupeaformis

The discussion of whitefish will refer to C. clupeaformis although Prosopium cylindraceum may have been found in the harbour occasionally.

Hamilton Harbour and Hamilton Beach

Coregonus clupeaformis catches peaked in the late 1870's then declined to low levels during the 1880's (Fig. 6). Coregonus clupeaformis was probably more abundant than the catch data indicate because its market value was low during this era (Whillans 1977). Increased catches and possibly abundance during the 1890's are difficult to explain. Christie (1973) and Whillans (1977) report that C. clupeaformis stocks in western Lake Ontario were low at this time. One possibility is that strong year classes in 1894 and 1898 may have substantially increased abundance locally (Whillans 1977). Another possibility is that increased gill net fishing during the 1890's (Fig. 3) masked a real decline in abundance during this period.

There is no record of the C. clupeaformis collapse in the harbour or at the beach, however Whillans (1977) states a small stock was maintained in the east end of the harbour until the early 1930's. By the late 1940's this stock was extirpated. Coregonus clupeaformis collapsed at the beach in 1964 although occasional catches were made until the mid-1970's (Fig. 7).

Bronte and Grimsby

Catches of C. clupeaformis at Bronte and Grimsby declined throughout the 1870's and 1880's (Fig. 6) while effort was increasing (Fig. 3). This suggests that C. clupeaformis abundance in western Lake Ontario was declining during this time.

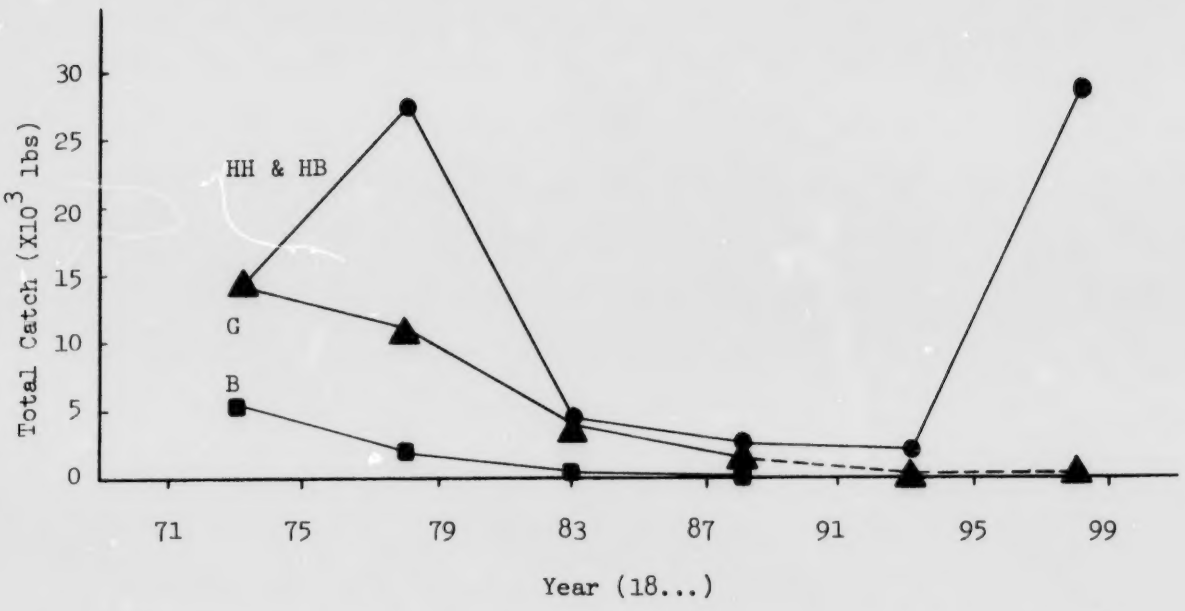


Fig. 6. Trends in the catch of Coregonus clupeaformis in western Lake Ontario, 1871-1900. B-Bronte; G-Grimsby; HH-Hamilton Harbour; HB-Hamilton Beach.

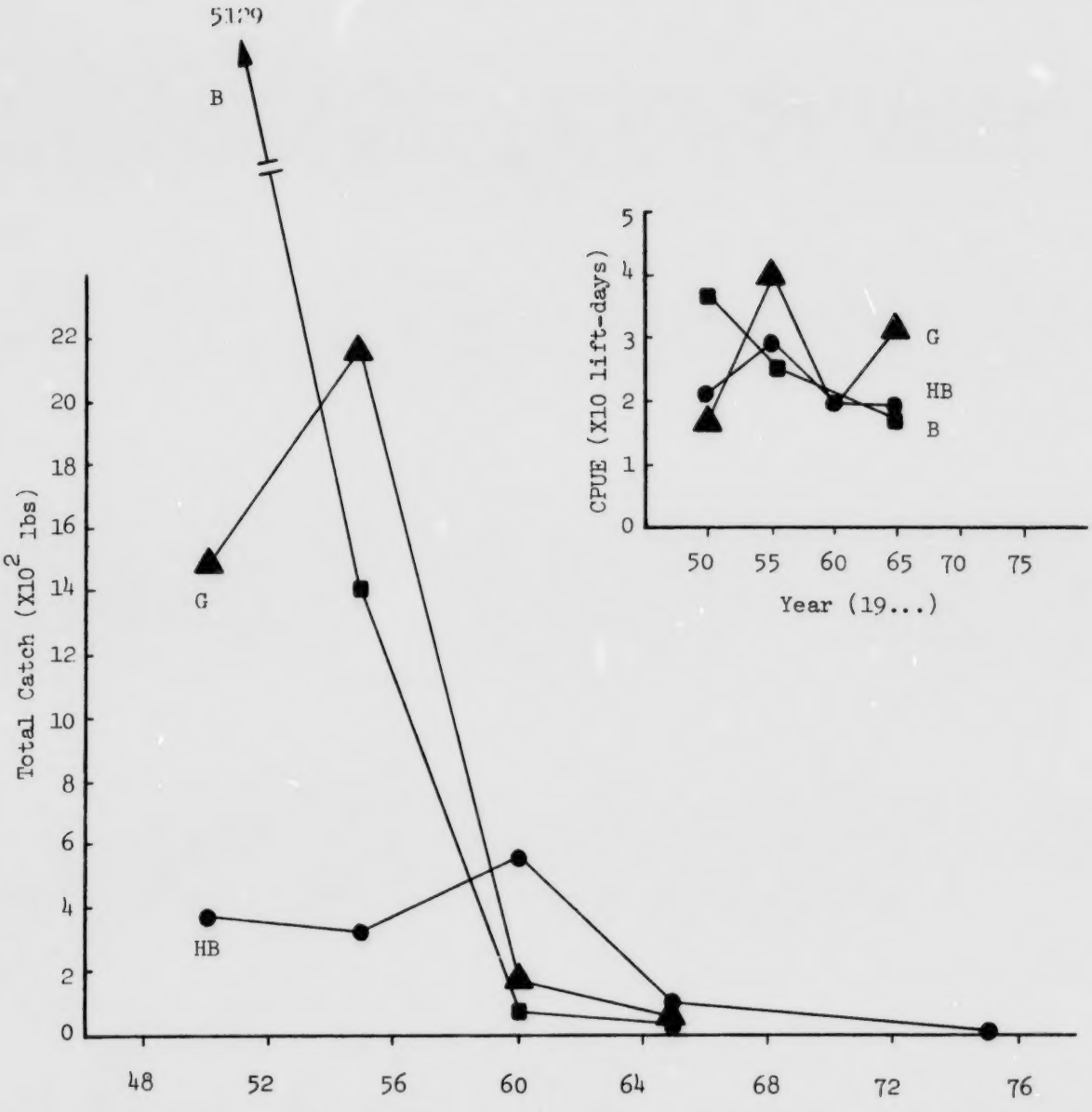


Fig. 7. Trends in the catch and CPUE of Coregonus clupeaformis in western Lake Ontario, 1948-1977. B-Bronte; G-Grimsby; HB-Hamilton Beach.

Between the turn of the century and the late 1940's a resurgence occurred. Catches at Bronte reached historic levels early in the 1950's and then declined as did CPUE (Fig. 7). Catches at Grimsby while never recovering to historic levels, also peaked in the early 1950's then dropped off. In the mid-1960's western Lake Ontario whitefish collapsed (Fig. 7).

Discussion of Coregonus clupeaformis

Hamilton Harbour was an important habitat for C. clupeaformis. A sizeable population of permanent residents existed and many more immigrated into the harbour in November to spawn. A second smaller feeding immigration occurred in June and July.

The decline of C. clupeaformis in the harbour was largely the result of deteriorating water quality which acted directly or indirectly by causing the disappearance of what was probably Ponteporeia affinis (a major food item) in the 1880's (Whillans 1977). Over-exploitation and an increase in the attack rate of the sea lamprey Petromyzon marinus in western Lake Ontario after 1953 were probably contributing factors as well (Christie 1973).

Re-establishment of C. clupeaformis in the harbour will probably be dependent on the success of local measures. As with herring much of the deep water habitat is unavailable because of anoxic conditions. However, the fact that a small stock survived in the east end of the harbour until the 1930's may mean that early historic water quality is not absolutely essential.

The historical use of the harbour by enormous numbers of seasonal migrants suggests re-establishing C. clupeaformis in the harbour would have significant effects on the fishery of western Lake Ontario.

Rainbow smelt Osmerus mordax

Osmerus mordax was first reported in the Canadian waters of Lake Ontario in 1931 (Mason 1933). By the 1950's O. mordax was abundant enough to comprise a major portion of the commercial catch in western Lake Ontario. Catches in all areas peaked in the mid-1950's and have declined since (Fig. 8). Catches in the Bronte area were much lower than in other areas because of lower fishing effort.

It is difficult to assess changes in the O. mordax populations from the catch and CPUE data because the larger catches in Lake Erie have affected the sale of Lake Ontario smelt (Christie 1973). It is probably safe to say O. mordax is extremely abundant at present. Little is caught commercially, however the annual spring spawning run is the basis of the major sport fishery in the harbour and at the beach (Hamilton Spectator, Apr. 20, 1976). The success of O. mordax in the last 40 years is largely owing to its ability to successfully occupy the vacant niche created by the demise of herring.

Re-establishment of the native salmonines and coregonines will probably affect the populations of forage species in western Lake Ontario.

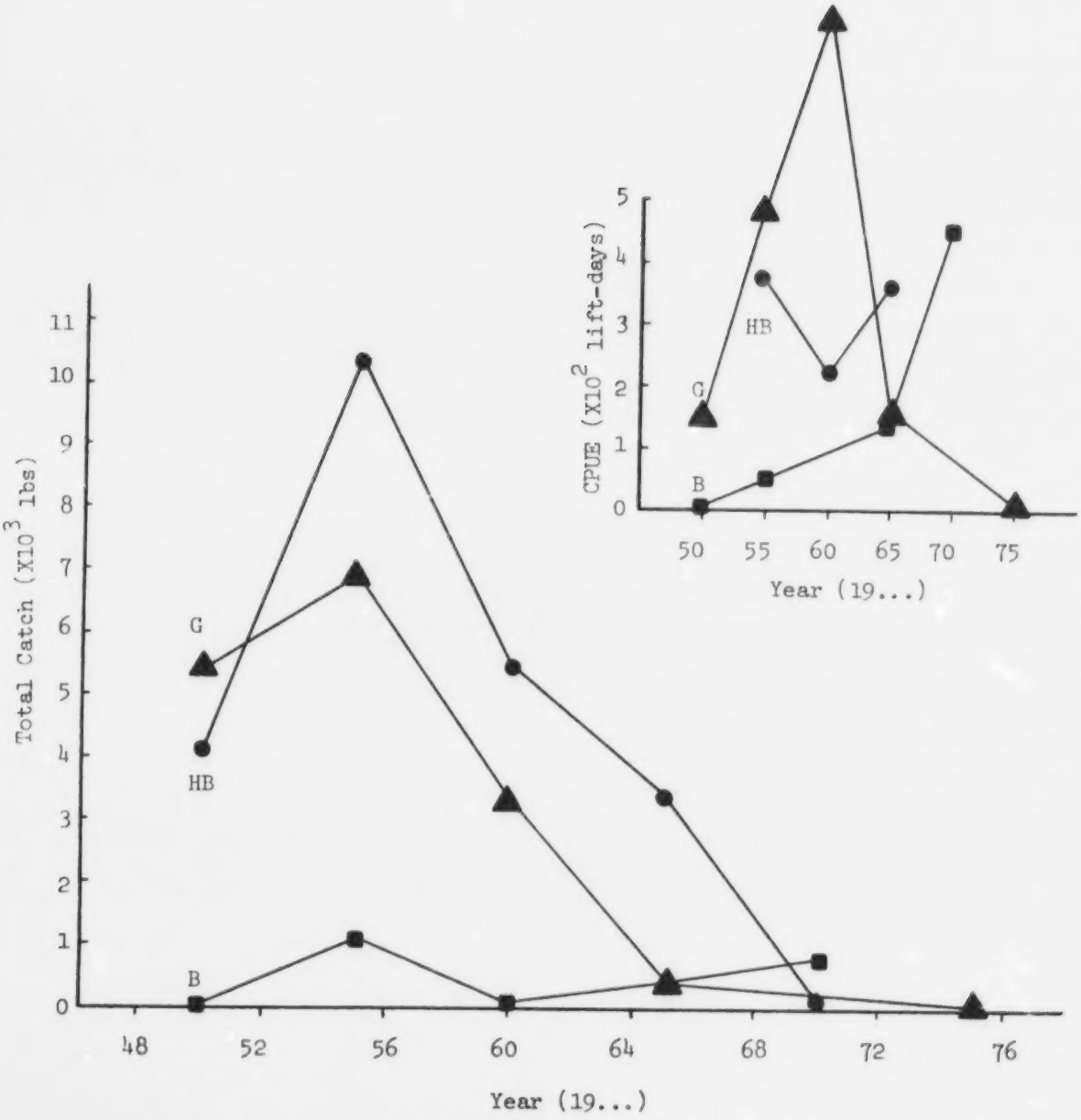


Fig. 8. Trends in the catch and CPUE of Osmerus mordax in western Lake Ontario, 1948-77. B-Bronte; G-Grimsby; HB-Hamilton Beach.

Osmerus mordax and A. pseudoharengus dominate the pelagic waters and are the primary forage species for S. namaycush and the introduced Pacific salmons (Regier 1979; Stewart et al. 1981). The ramifications of manipulating forage fish populations will have to be carefully assessed. Intense pressure from sport fishermen make it unlikely that the stocking of Pacific salmon will be discontinued in the foreseeable future.

Atlantic salmon Salmo salar and Lake sturgeon Acipenser fulvescens

Records do not exist to confirm the presence of a fishery for S. salar in Hamilton Harbour. However, it is highly unlikely that the European settlers would fail to exploit this species. In other areas such as Toronto, exploitation was intense (Wainio and Hester 1973). Both Redhill and Spencer Creeks were known to support large spawning runs in the early 1800's (Kerr and Kerr, Sept. 5, 1868). In the 1830's S. salar began to decline and by the late 1860's was all but extinct in the harbour (Kerr and Kerr, Sept. 5, 1868). A short-lived resurgence occurred in 1881-1882 but afterwards S. salar disappeared (Whillans 1977).

Salmo salar was a migrant species which used the tributary streams of the harbour to spawn. Over-exploitation and the effects of land clearing activities on the streams (warming, damming, silting of spawning areas and altered flow regime) in the early 1800's were the primary factors in the decline of S. salar in the harbour and Lake Ontario (Christie 1973; Regier 1979).

Acipenser fulvescens was found in large numbers in the harbour in the 1860's (Kerr and Kerr, Sept. 5, 1868). Evidently A. fulvescens was not sought by the commercial fishermen because it did not appear in the catch records until 1886. The size of the catch between 1886 and 1900 demonstrates the lack of commercial interest in lake sturgeon (Table 1). The catch records do show that A. fulvescens abundance declined until the 1890's when a small increase occurred.

There is good evidence that indicates A. fulvescens was probably a permanent resident in Hamilton Harbour (Whillans 1977). Exploitation, even at a low level would be enough to seriously deplete lake sturgeon given the lateness of sexual maturity (Scott and Crossman 1973). Although there is no evidence of spawning in the harbour it is presumed that Redhill and Spencer Creeks were utilized (Whillans 1977) and possibly coarse gravel shoals along the north and south shores of the outer basin (Fig. 15). Fishing pressure probably caused the extinction of A. fulvescens in the harbour. Lake sturgeon were considered a worthless nuisance that ruined nets set for "valuable" species (Harkness and Dymond 1961). When caught they were killed and dumped back into the water, thrown up on shore, dried and burned or buried in the soil as fertilizer (Harkness and Dymond 1961).

It is unlikely that S. salar or A. fulvescens could ever be re-established in Hamilton Harbour.

2.2.2 WARMWATER SPECIES

Historically, Hamilton Harbour, Cootes Paradise, Ashbridge's and Toronto Bay were the most important warmwater fish habitats in western Lake Ontario. Hamilton Harbour still retains this function even though 74% of the marsh area has been lost (Whillans 1982).

The warmwater species in Hamilton Harbour are permanent residents. They have not attracted as much commercial interest as the salmonines and coregonines.

The abundant warmwater habitat in the harbour generally had a buffering effect against stress imposed by poor water quality, habitat destruction and exploitation in the late 1800's. Nevertheless significant changes have occurred in the warmwater community.

Northern Pike Esox lucius

Most of the commercial catch of E. lucius was taken from the harbour (Fig. 9). Little can be inferred from the historic records about the changes in the E. lucius population. A major portion of the catch in the late 1800's was caught by spearing in the winter. Warm weather and muddy water often disrupted the fishery even though pike were abundant (Kerr and Kerr 1860-1898). It would be reasonable to assume that E. lucius abundance declined somewhat before the turn of the century as the catch records show (Fig. 9), however the magnitude of the decline is unknown. Deteriorating water quality as a result of the construction of a collector sewer from Hamilton into the harbour in 1888 is the probable cause (Kerr and Kerr, March 6, 1888).

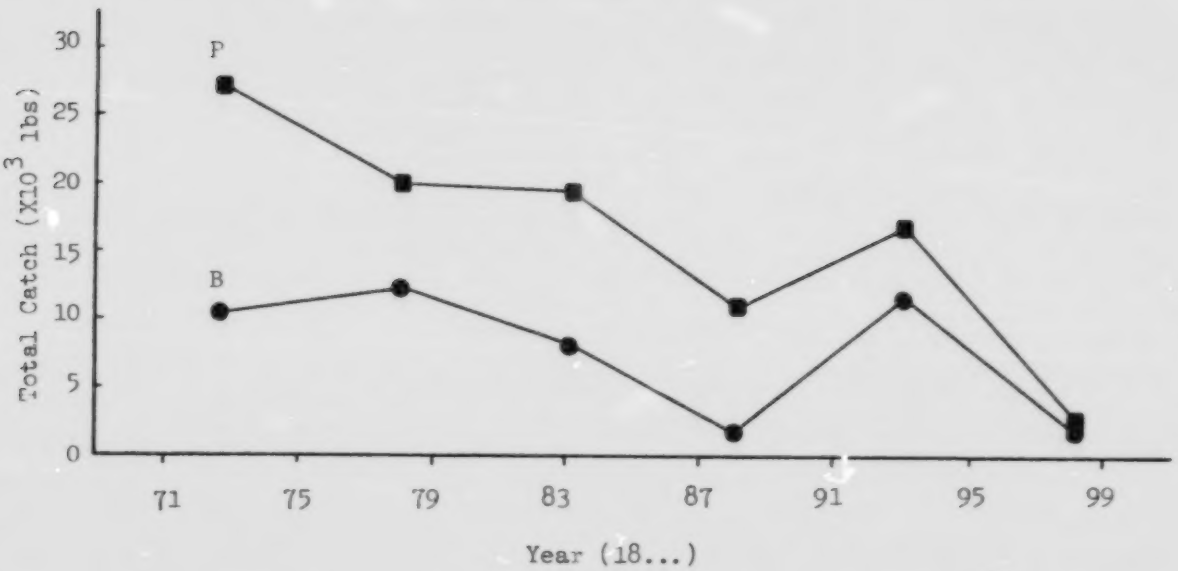


Fig. 9. Trends in the catch of Esox lucius and Micropterus sp. in Hamilton Harbour and at Hamilton Beach, 1871-1900. P-E. lucius; B-Micropterus sp.

The abundance and catch of E. lucius in western Lake Ontario has always been low primarily because little habitat exists (Table 1).

The recent commercial fishery in the harbour did not catch any E. lucius (Table 1). These statistics are misleading because the focus of the fishery was carp, Cyprinus carpio not E. lucius. Today, E. lucius is less abundant in Cootes Paradise and rare in the harbour relative to the historical situation.

Discussion of Esox lucius

The nature of the historic fishery in the harbour and the virtual absence of E. lucius in western Lake Ontario suggests that the decline of pike in the harbour and Cootes Paradise was due entirely to local events. During the late 1800's deteriorating water quality in Cootes Paradise and along the south shore plus widespread pollution after the construction of the Hamilton collector sewer in 1888 had some impact on E. lucius populations.

More important was the loss of prime marsh habitat along the southern shore of the harbour to shoreline restructuring activities which began in earnest in 1909 (Ozanian 1957; Hamilton Harbour Comm. 1976 cited in Whillans 1977). These stresses combined with heavy sport fishing pressure in the 1800's and early 1900's reduced E. lucius to levels from which it has not fully recovered.

Given that the trend towards improving water quality continues, E. lucius populataions in the harbour could probably be increased significantly if suitable habitat were supplied. In Cootes Paradise the situatuion is far better. Esox lucius is common during spring spawning (Whillans 1977).

Bass Micropterus sp.

Black bass M. dolomieui and M. salmoides, were the most abundant bass in the harbour and Cootes Paradise during the 1860's (Kerr and Kerr, Sept. 5, 1868). They were largely caught by spearing although incidental catches in gill nets and seines must have occurred as well.

Micropterus sp. were extremely abundant during the 1870's and catches were large (Fig. 9). During the 1880's abundance and catches declined possibly as a result of numerous localized toxic events along the southern shore and the widespread pollution caused by the completion of a collector sewer from Hamilton in 1888 (Kerr and Kerr, March 6, 1888). A short recovery occurred during the early 1890's followed by a decline (Fig. 9). These observations parallel closely changes in bass abundance documented by Whillans (1977). Micropterus sp. were not caught by the recent commercial fishery because it was focussed on C. carpio.

Catches of Micropterus sp. in western Lake Ontario were historically low because little suitable habitat existed (Table 1). In recent years Micropterus sp. has not been caught because its habitat has virtually disappeared (Whillans 1982). Traces may be found at the mouths of various tributary streams.

Discussion of *Micropterus* sp.

The available evidence suggests that the reduction in bass populations in the harbour and Cootes Paradise was due entirely to local events. Deteriorating water quality but more importantly the loss of important habitat along the south shore were major stresses. In addition "evidence had been secured sufficiently convincing to show that ... the rapid disappearance of the bass was in no small measure due to winter spearing, for which many licenses have been issued in the past ...". (Ont. Game and Fish Comm. 1912). At present *M. salmoides* is rare in Cootes Paradise and *M. dolomieui* is common in comparison to historic abundances (Whillans 1977).

The bass and pike fisheries in the harbour and Cootes Paradise have always been closely associated and have undergone similar changes in abundance. As with *E. lucius* this suggests that the prime requirement to increase *Micropterus* sp. populations is the supply of suitable habitat. Water quality is less of a factor however, continued improvement is desirable.

Catostomidae *Catostomus* sp. and *Moxostoma* sp.

Historically the identification of *Catostomus* sp. and *Moxostoma* sp. was often confused (Whillans 1977). They will be discussed together.

It is difficult to determine exactly how large the fishery for suckers was in the harbour. Catches were included with sheepshead and other species under coarse fish in the Department of Marine and Fishery records (1868-1915). It is likely however, that Catostomidae comprised a large portion of the coarse fish catch in the harbour because they were actively

sought in the spring (Kerr and Kerr, Apr. 16, 1873). Increasing catches of coarse fish between 1871 and the turn of the century may partially reflect an increase in the abundance of Catostomidae in the harbour (Table 1).

Records covering later years are scarce. Between 1948 and 1977 sporadic catches were made by commercial fishermen in the harbour and Cootes Paradise (Table 1). Records from the beach indicate that sucker abundance increased during the 1950's and declined substantially by the mid-1960's (Fig. 10). Reduced competition and the compatibility of at least C. commersoni with an enriched environment are probably the reasons for the increase in the 1950's (Whillans 1977). The decline during the 1960's is puzzling. It is possible that the fast rise and fall of water levels in the spring of 1961 may have had some influence by disrupting spawning activity. Catostomus commersoni is presently the dominant catostomid in the harbour (Whillans 1977).

Discussion of Catostomidae

Catostomid abundance in the harbour and Cootes Paradise has fluctuated periodically as a result of enrichment and other changes in water quality. Rehabilitation of the harbour and Cootes Paradise for other more sensitive species may have a positive effect on C. commersoni and M. macrolepidotum. It is unlikely that measures applying specifically to suckers need to be taken.

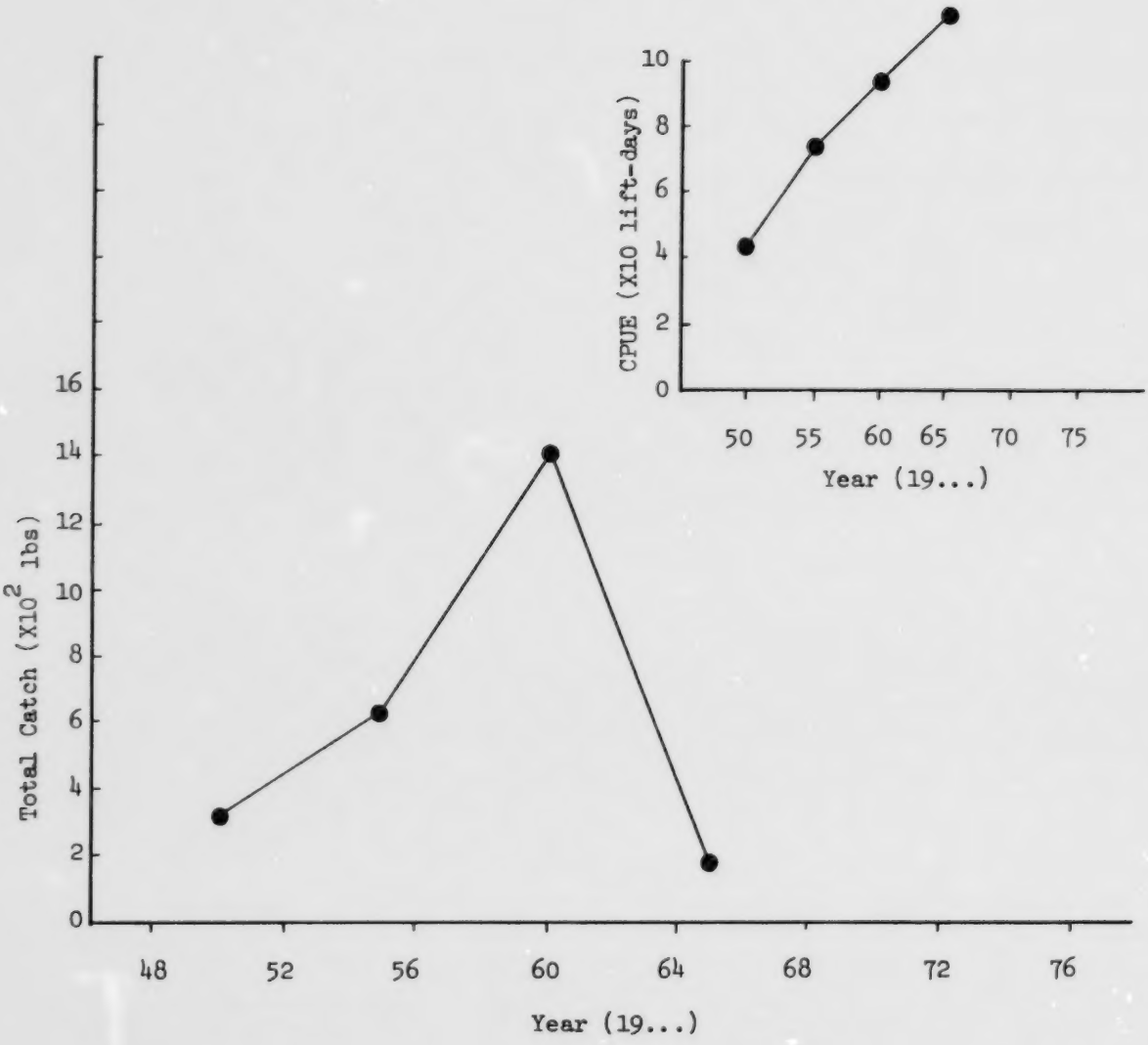


Fig. 10. Trends in the catch and CPUE of Catostomidae at Hamilton Beach, 1948-77.

Yellow Perch Perca flavescens

Perca flavescens was first segregated in the catch records from other coarse fish in 1894. This is "normally a sign that a species has achieved importance to the fishery" (Christie 1973). Historically P. flavencens was recorded at Hamilton Beach and Grimsby only. The catches at the beach were probably made in the harbour. Perca flavescens was observed spawning on the spring seining grounds and was caught in gill nets in this area during the spring (Kerr and Kerr, March 15, 1868, Apr. 15, 1889).

Between 1894 and 1900 P. flavescens abundance increased dramatically (Table 1). Reduced seining (Fig. 3) and lower predation by E. lucius (and S. namaycush) were the contributing factors (Whillans 1977). At Grimsby P. flavescens was caught in 1899 only (Table 1).

Catches of P. flavescens at Grimsby were sporadic during the 1950's and 1960's (Table 1). At Hamilton Beach abundance decreased until the mid-1960's after which an increase occurred (Fig. 11). Perca flavescens is common in the harbour at present.

Discussion of Perca flavescens

Perca flavescens abundance in the harbour has fluctuated in response to local events such as reduced fishing, loss of aquatic macrophytes and localized toxic events. These fluctuations, being confined to the harbour, have gone virtually unnoticed in Lake Ontario where P. flavescens has been abundant since the 1930's (Christie 1973).

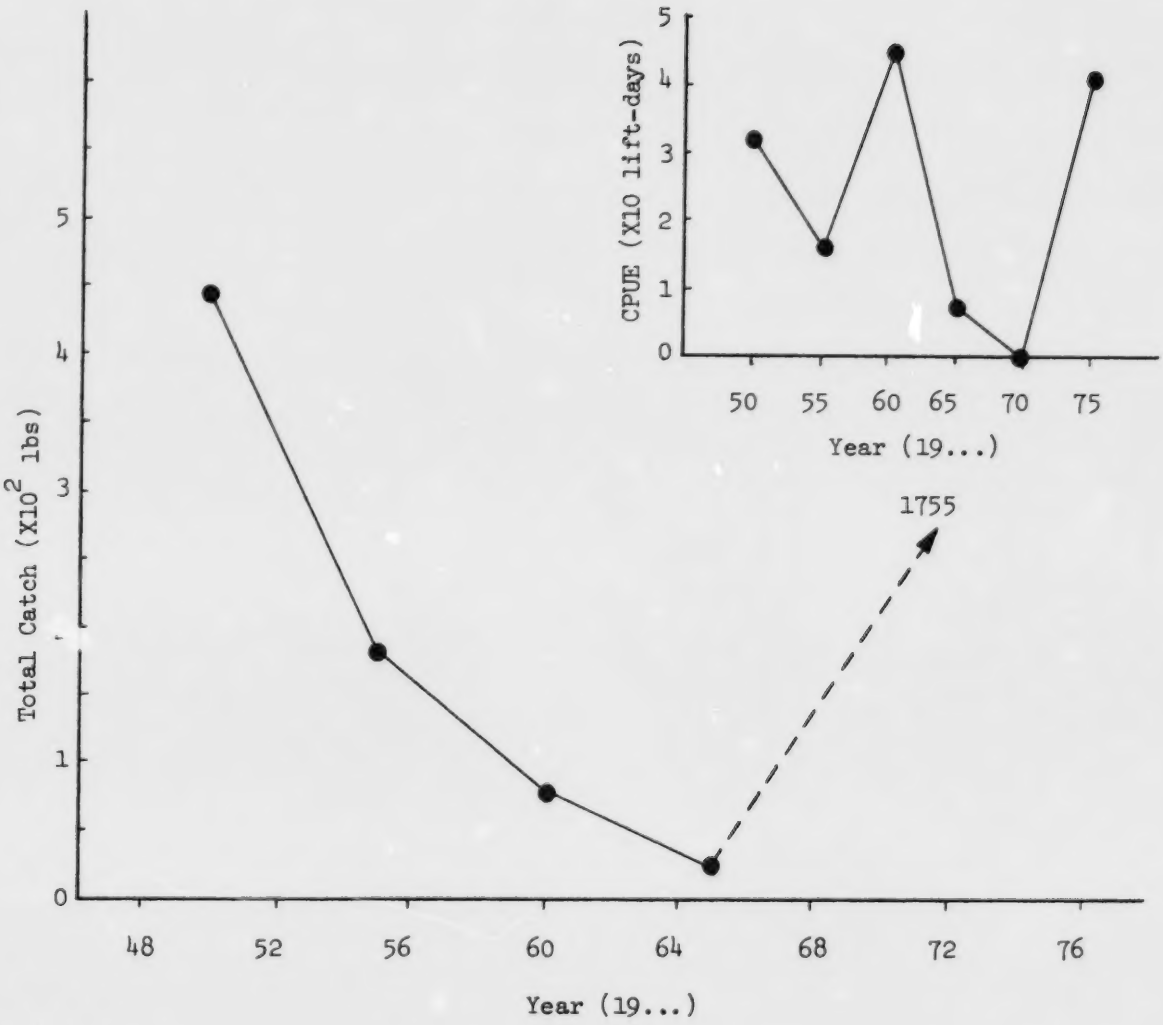


Fig. 11. Trends in the catch and CPUE of Perca flavescens at Hamilton Beach, 1948-77.

Given the ubiquitous nature of yellow perch it is unlikely any measures directly affecting P. flavescens would need to be taken.

White bass Morone chrysops

Morone chrysops was first identified in Hamilton Harbour in 1866 (Kerr and Kerr, May 18, 1866). But it is only in recent years that M. chrysops has been caught in the commercial fishery (Table 1, Fig. 12). Catches of M. chrysops at Hamilton Beach show a decline in abundance in the late 1950's followed by a small revival during the 1970's (Fig. 12).

Records pertaining to Bronte and Grimsby show that M. chrysops was caught very infrequently (Table 1). A slight increasing trend was observed at Grimsby in the late 1970's.

Discussion of Morone chrysops

Morone chrysops is a recent addition to the commercial fishery. It has never been a major component nor does it appear likely to become one in the foreseeable future. What meagre evidence there is concerning changes in abundance in the harbour suggests that all occurred in response to local events (i.e. reduction of aquatic macrophytes). Currently M. chrysops abundance is low and M. americana is dominant within the harbour (Whillans 1977).

It is probable that rehabilitation of the harbour would have some effect on white bass and white perch populations. If the effects were negative, immigration from Lake Ontario is a possible scenario which cannot be overlooked.

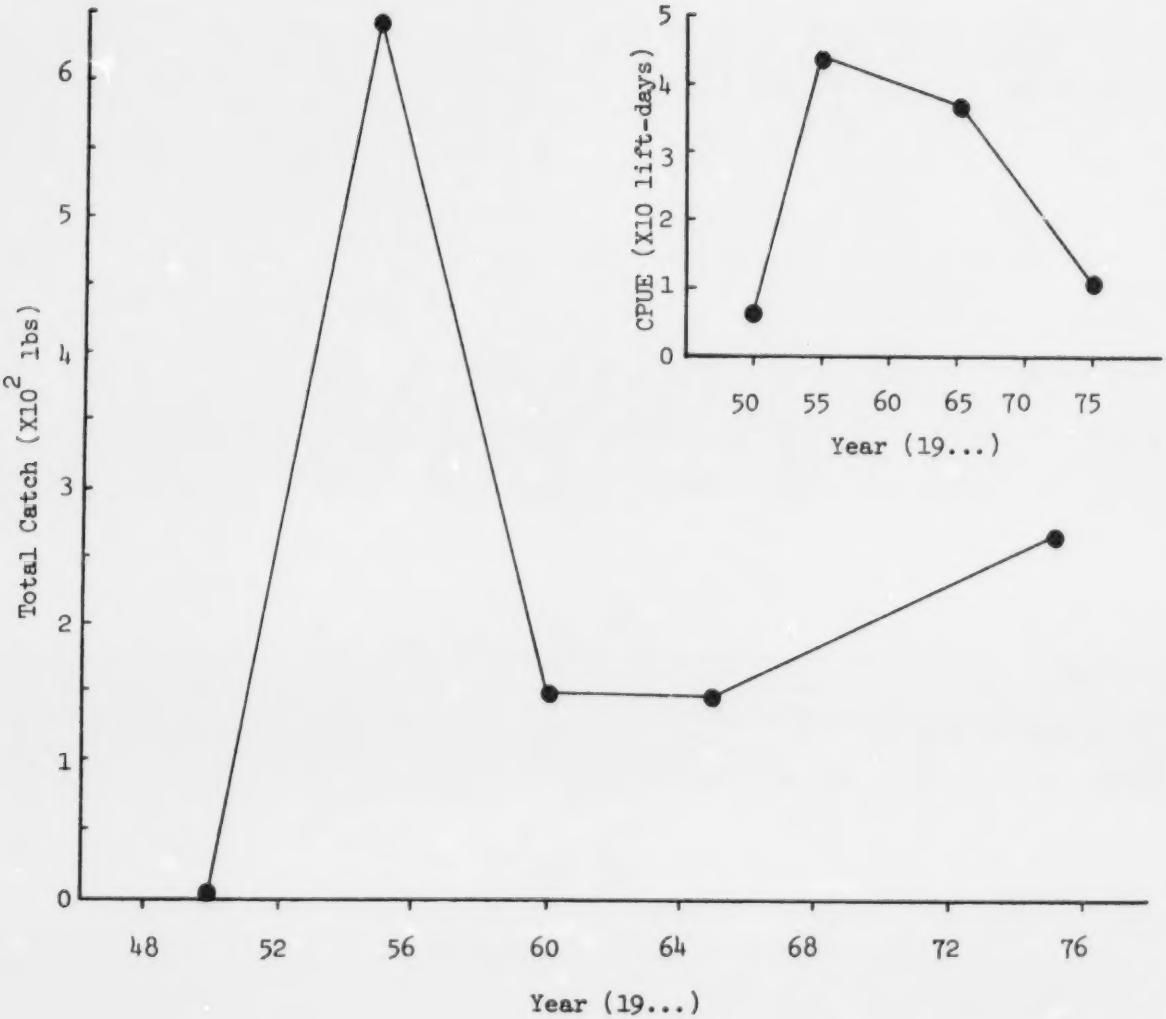


Fig. 12. Trends in the catch and CPUE of Morone chrysops at Hamilton Beach, 1948-77.

Carp Cyprinus carpio

Historically the commercial records do not record C. carpio as part of the catch. It seems likely that scattered catches were made around the turn of the century because C. carpio was extremely abundant in the harbour by 1910. Carp populations continued to increase during the 1920's and 1930's (Whillans 1977).

By the late 1940's C. carpio was virtually the only species caught in the commercial fishery in the harbour and Cootes Paradise. Catches in Cootes Paradise peaked in the mid-1950's, then declined and ceased altogether in the early 1960's (Fig. 13). In the harbour, catches declined from the early 1950's mostly as a result of a reduction in effort (Fig. 13). A carp control project in Cootes Paradise from 1951-1956 removed close to 84,000 pounds of carp which apparently decreased abundance temporarily (Roy. Bot. Gdns. ca. 1958). These catches do not reflect the abundance of carp in the harbour. Cyprinus carpio continues to be one of the most abundant species in the harbour at present. Catches of C. carpio in western Lake Ontario are summarized in Table 1.

Discussion of Cyprinus carpio

Cyprinus carpio abundance has increased dramatically because of the degraded conditions in the harbour and Cootes Paradise. The ubiquitous nature of C. carpio has allowed it to fill open niches created by the reduction of other species due to deteriorating water quality (i.e. increasing turbidity and nutrient enrichment) (Whillans 1977).

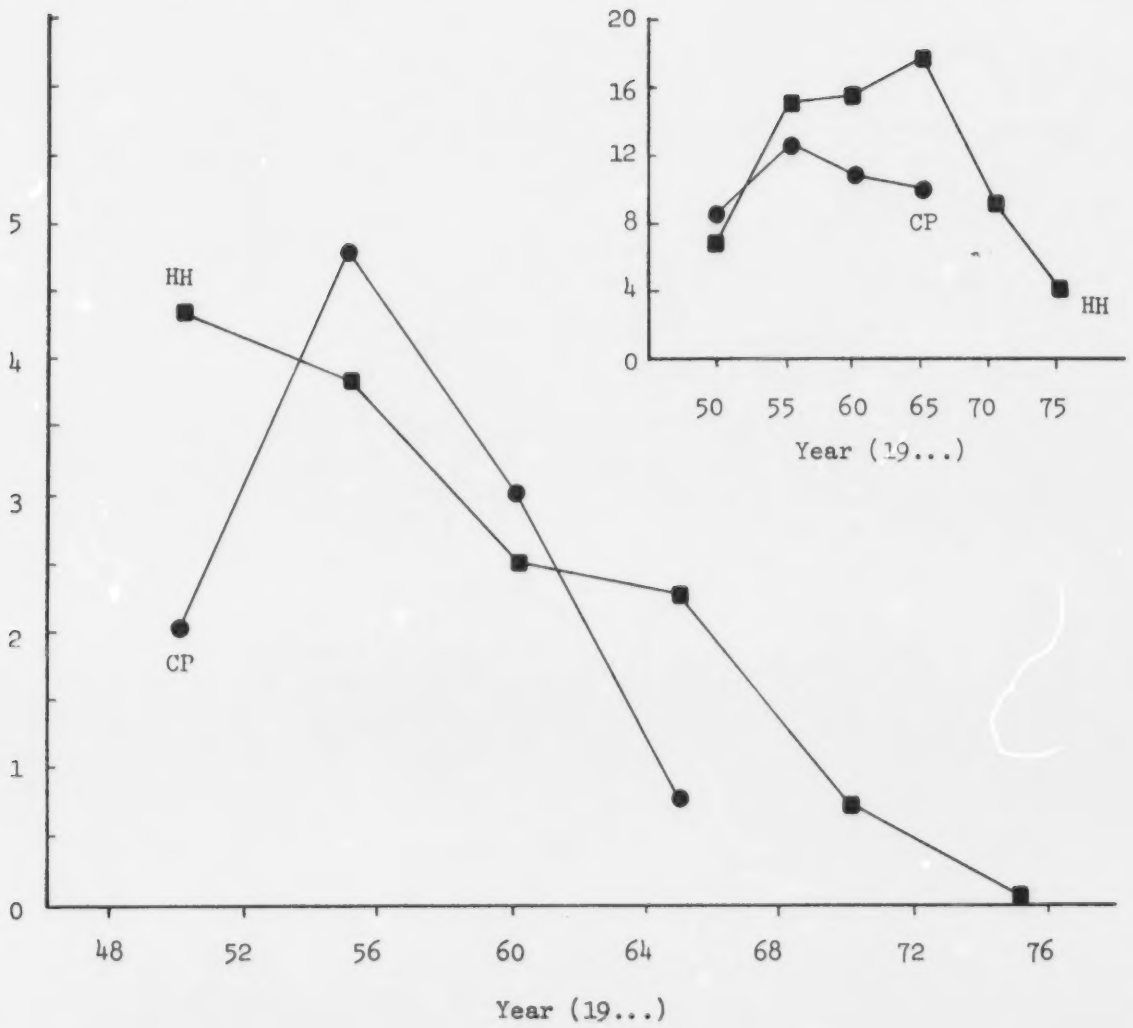


Fig. 13. Trends in the catch and CPUE of Cyprinus carpio in Cootes Paradise and Hamilton Harbour, 1948-77. CP-Cootes Paradise; HH-Hamilton Harbour. Catches in Cootes Paradise do not include catches made for carp control purposes from 1951-56 by the Royal Botanical Gardens.

Rehabilitation of the fisheries in the harbour, particularly the warm water fisheries will probably require measures to control carp. Harris et al. (1982) suggest that while the methods of control are unknown the problem is approachable through ideas developed in integrated pest management and sea lamprey control in the Great Lakes.

2.2.3 MISCELLANEOUS SPECIES

Table 1 summarizes the catch data of other species caught in the commercial fishery. These species were either caught sporadically and/or in such low quantities that no trends were visible. None was ever a major component of the fishery.

2.3 STATUS OF THE COMMERCIAL FISHERY

"Overall the change in the fish associations in the Great Lakes during the past two centuries has involved a massive shift from high valued, long-lived, benthic species to low valued, small, short-lived pelagic species" (Regier 1979). In Hamilton Harbour this shift from a viable coldwater fishery in which S. namaycush, Coregonus sp., C. clupeaformis and C. artedii dominated towards a fishery dominated by P. flavescens, M. chrysops and exotic species such as O. mordax, and C. carpio (Table 2) is largely the result of poor water quality, size-selective exploitation and habitat destruction. The most stressful perturbation was deteriorating water quality (Whillans 1979). Though the commerical fishery has been able to use some of the species which currently dominate, it is very much reduced in extent (Table 2).

Table 1. Miscellaneous commercial catches, 1871-1978. All figures are in pounds

Taxon		Cootes Paradise	Hamilton Harbour	Hamilton Beach	Bronte	Grimsby
Carp	1871-1901	-	-	-	-	-
	1948-1978	G	G	3118	1065	8
Ictaluridae	1871-1901	-	-	3260	-	-
	1948-1978	3405	6233	1	-	1
Catostomidae	1871-1901	-	-	-	-	-
	1948-1978	2581	3740	G	2885	345
Sturgeon	1871-1901	-	-	12300	-	2130
	1948-1978	-	-	-	-	-
Lake Trout	1871-1901	-	4700	G	G	G
	1948-1978	-	-	63	5754	4648
Whitefish	1871-1901	-	31150	G	G	G
	1948-1978	-	-	G	G	G
Herring	1871-1901	-	G	G	G	G
	1948-1978	700[a]	660[a]	181[a]	1165[c]	34895[c]
Burbot	1871-1901	-	-	-	-	-
	1948-1978	-	-	11	-	-
Coho salmon	1871-1901	-	-	-	-	-
	1948-1978	-	-	1799	-	15711
Chinook salmon	1871-1901	-	-	-	-	-
	1948-1978	-	-	-	-	1481
Perch	1871-1901	-	-	73302	-	5000
	1948-1978	-	-	G	155	11548
Walleye	1871-1901	-	-	11600	-	17500
	1948-1978	-	-	21	-	126
Blue pickerel	1871-1901	-	-	-	-	-
	1948-1978	-	-	440	-	1455
Muskellunge	1871-1901	-	-	11000	-	3600
	1948-1978	-	-	-	-	-
Northern pike	1871-1901	-	G	G	16220	300
	1948-1978	-	-	17	-	1

Table 1. (continued)

Taxon		Cootes Paradise	Hamilton Harbour	Hamilton Beach	Bronte	Grimsby
Eels	1871-1901	-	5225	17145	1600	600
	1948-1978	-	4	22	-	149
Centrarchidae	1871-1901	-	G[e]	G[e]	8100[e]	24600[e]
	1948-1978	500	14	1936	575	-
Smelt	1871-1901	-	-	-	-	-
	1948-1978	800	1955	28149[b]	G	G
Alewife	1871-1901	-	-	-	-	-
	1948-1978	-	-	340	100	-
Gizzard shad	1871-1901	-	-	-	-	-
	1948-1978	-	-	3830	200	-
White perch	1871-1901	-	-	-	-	-
	1948-1978	-	-	38	-	448
White bass	1871-1901	-	-	-	-	-
	1948-1978	-	-	G	4938	3988
Coarse fish	1871-1901	-	57300	306062	77350	41900
	1948-1978	-	-	-	445[d]	5[d]

a - pilots, tullibees, etc. (Coregonus sp.); b - caught with seines;
c - chubs (Coregonus sp); d - freshwater drum; e - Micropterus sp.;
G - see Figs. 2-13

Table 2. Changes in the status of fish taxa in the commerical fisheries in the vicinity of Hamilton Harbour. Status is based on abundance and the importance of a taxon to the commercial fishery.

Taxon	1871-1900					1948-1977				
	CP	HH	HB	B	G	CP	HH	HB	B	G
Salvelinus namaycush	X	L	M	L	M	X	E	E	E	E
Coregonus artedii and Coregonus sp.	X	VH	VH	H	H	X	E	E	E	E
Coregonus clupeaformis	X	H	H	M	M	X	E	E	E	E
Esox lucius	VH	VH	L	X	R	M	R	R	R	R
Micropterus sp.	H	H	L	R	R	M	L	R	R	R
Catostomidae	M	M	M	L	L	M	M	L	R	R
Perca flavescens	X	X	L	X	L	X	X	M	R	M
Cyprinus carpio	X	X	X	X	X	VH	VH	L	L	R
Osmerus mordax	X	X	X	X	X	L	L	H	H	H

Areas : CP - Cootes Paradise; HH - Hamilton Harbour; HB - Hamilton Beach; B - Bronte; G - Grimsby

Abundance: VH - very high; H - high; M - moderate; R - rare; L -low; E - extinct; X - not recorded

The information documented from the commercial catch records indicates Hamilton Harbour was an important spawning, nursery and feeding habitat for salmonine and coregonine stocks in western Lake Ontario. All of the available evidence suggests that poor water quality limits the availability of the existing cold water habitat in the harbour. Rehabilitation measures aimed at re-establishing a coldwater fishery in the harbour would almost certainly have important effects on the fishery of western Lake Ontario because of the migratory behaviour these species exhibited historically.

The changes in the status of the warmwater fishery are less dramatic (Table 2). Historically a productive fishery for species such as E. lucius and Micropterus sp. existed. While these species have been affected by the same stresses which extirpated the coldwater fishery, the overall impact has been much less. Nevertheless, remedial measures aimed at improving the status of E. lucius and Micropterus sp. and other warmwater species are generally held to be possible at this time.

There is good evidence which suggests that a lack of habitat, especially in the outer basin of the harbour, is presently limiting warmwater species. While poor water quality appears to have been less of a factor it may still be a problem if species such as Stizostedion vitreum, which were present historically (Kerr and Kerr 1860-1898), are desired.

3. SPORT FISHING

There does not appear to be any good way of retrospectively examining the sport fishery in Hamilton Harbour. The last major sport fishery collapsed in the late 1920's and early 1930's (Stud. Burl. Bea. Bung. School 1943 cited in Whillans 1977). Consequently surviving witnesses would be very old now. The only source of reliable information seems to be newspaper accounts and diaries.

Sport fishing was a popular activity in Hamilton Harbour during the 1800's. Fishermen angled and trolled for pike and bass from piers and boats during the summer (Kerr and Kerr, Jan. 20, 1885) (Table 3). Thousands of black bass were caught by trollers and eels were caught with hooks and lines (Kerr and Kerr, July 30, 1883, Jan. 5, 1891) (Table 3).

Spearing was permitted during the winter beginning in 1864. Except for temporary bans in 1874 and 1896, which were revoked under heavy political pressure (Kerr, Feb. 10, 1894), spearing continued well into the 1920's.

The rapid increase in the popularity of spearing is evident from accounts of fish huts on the ice. In 1866 at least 50 huts were seen on the ice (Kerr and Kerr, Feb. 8, 1866). An 1891 survey found that 220 licenses had been issued that year. This represented a substantial financial investment since most of the licensees owned their own huts, spears, decoys and other necessary equipment (Hamilton Herald, Jan. 29, 1892). By 1892 "... frequently as many as two or three hundred of these huts [could] be counted on the surface of the bay ..." (Anonymous 1892).

Table 3. Changes in the taxa, relative abundance and location of the sport fishery in Hamilton Harbour. Abundance is the opinion of the author based on comments from referenced sources.

Year	Abundance	Location	Reference
1626-1627	*Salmo salar* fishing excellent	Spencer Creek	Woodhouse 1965a
1802	*S. salar* and whitefish *C. clupeaformis* fishing good	Spencer Creek	Woodhouse 1965b
1865	Spearing for pike and bass excellent	south and west of Desjardins Canal in the Harbour and around Carroll's Point	Kerr and Kerr, Jan. 25 and 28, 1865
1865	Spearing for pike and bass is good	in the Harbour and near the Beach south of the canal	Kerr and Kerr, Feb. 1, 1865
1865	Spearing for pike, bass and sunfish good	Cootes Paradise	Kerr and Kerr, Oct. 13 and 14, 1865
1866	Herring spearing excellent	Hamilton Harbour	Kerr and Kerr, Dec. 7, 1865
1866	Pike and bass spearing excellent largest catch ever 45 barrels	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, March 3, 1866 February 20, 1867
1867	Pike and bass spearing excellent 90 barrels caught	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, Jan. 24, 1868
1870	Herring spearing good	Hamilton Harbour near Desjardins Canal	Kerr and Kerr, Nov. 25, 1870
1870	Herring, eels, pike and other rough fish plentiful	Hamilton Harbour and Dundas Marsh	Kerr and Kerr, Jan. 7, 1871
1871	Herring spearing excellent; pike and bass spearing poor	Hamilton Harbour	Kerr and Kerr, Jan. 12, 1872

Table 3. (continued)

Year	Abundance	Location	Reference
1872	Pike and bass spearing excellent; herring spearing fair	Hamilton Harbour	Kerr and Kerr, Jan. 20, 1873
1874	Salmon, herring, ciscos caught in abundance on hooks and lines	Hamilton Harbour	Kerr and Kerr, Nov. 7, 1874
1876	Eels, pike and bass caught in abundance	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, Sept. 6, 1876
1877	Pike and bass abundant	Hamilton Harbour	Hamilton Evening Times, April 6, 1877
1879	Spearing for pike and bass good	Hamilton Harbour	Kerr and Kerr, Feb. 7, 1879
1879	Herring are scarce spearing cancelled	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, Oct. 31, 1879
1882	fishing poor	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, April 29, 1882
1883	Bass and pike spearing is excellent	Hamilton Harbour	Kerr and Kerr, Feb. 1, 1883
1883	Pike spearing good	around Big Creek-Hamilton Harbour	Kerr and Kerr, Feb. 26, 1883
1883	Eels caught with hooks and lines	Hamilton Harbour	Kerr and Kerr, July 30, 1883
1883	Bass angling excellent	Hamilton Harbour	Kerr and Kerr, Sept. 3, 1883
1883	Angling and trolling were successful "as it always is"	Hamilton Harbour	Kerr and Kerr, Jan. 10, 1884
1884	Spearing is good (pike and bass?)	Hamilton Harbour	Kerr and Kerr, February 4, 1884

Table 3 (continued)

Year	Abundance	Location	Reference
1884		most spearing carried on around Carroll's Point and Desjardins Canal - a few huts are scattered half way down to Rock Bay	Hamilton Spectator, Feb. 18, 1884
1884	angling and trolling for bass and pike, etc. excellent	Hamilton Harbour	Kerr and Kerr, Jan. 20, 1885
1885	fishing splendid (perch and eels, etc.?)	along the drop off along the southern shore of Hamilton Harbour	Halcrow 1970
1886	Anglers catch large quantities of pike during the summer - fish frequently perish	Hamilton Harbour	Kerr and Kerr, Feb. 6, 1886
1886	Pike and bass spearing failed - water muddy	Hamilton Harbour	Kerr and Kerr, March 4, 1886
1886	at least 10,000 pike shot (per year?)	Hamilton Harbour	Kerr and Kerr, April 20, 1886
1886	Bass have diminished or grown wary; trollers used to fish for pike and bass	Hamilton Harbour off Land's Wharf and many other places in the harbour	Hamilton Spectator, Aug. 17, 1886
1886	Only pike and herring can be speared - bass are diminishing	Hamilton Harbour	Kerr and Kerr, Dec. 3, 1886
1887	Hundreds of bass under the ice	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, Jan. 6, 1887
1888	Spearing for pike, bass and herring good	Hamilton Harbour	Kerr and Kerr, Jan. 15, 1888

Table 3. (continued)

Year	Abundance	Location	Reference
1888	Herring and pike spearing excellent - twice as many huts on the ice as ever seen before - perch caught with hooks and lines	Northwest part of Hamilton Harbour	Hamilton Spectator, Feb. 6, 1888
1888	Pike and bass spearing poor during the winter	Hamilton Harbour	Kerr and Kerr, March 25, 1888
late 1880's early 1890's	good pike and bass fishing	South shore of Hamilton Harbour near Land's Wharf - Emerald Street	Hamilton Federation of Environmental Groups (1972)
1890	large bass are being hauled out	Hamilton Harbour	Hamilton Spectator, Aug. 10, 1970
1891	few bass caught with spears in winter - mostly pike; black bass caught in thousands by trollers during the summer	Hamilton Harbour	Kerr and Kerr, Jan. 5, 1891
1891	spearing very poor - Fisheries Dept. cancels it	Hamilton Harbour and Cootes Paradise	Kerr and Kerr, Jan. 24, 1891
1892	4-6 times more pike speared than bass; spearing privilege still cancelled	Hamilton Harbour and Cootes Paradise	Hamilton Herald, Jan. 29, 1892
1896	Largemouth bass, speckled bass, sunfish catfish and eels are speared	Hamilton Harbour	Kerr and Kerr, Nov. 30, 1896
1897	Spearing is poor (pike, bass and herring?)	Hamilton Harbour	Hamilton Evening Times, Feb. 6, 1897

Table 3. (continued)

Year	Abundance	Location	Reference
1904	Bass, perch and sunfish angling excellent spring to fall	Hamilton Harbour	Hamilton Spectator, April 10, 1929
1905	Perch, sunfish and bass fishing excellent	Spencer Creek	Woodhouse (1965a)
1911	Large quantities of carp and pike speared	Hamilton Harbour	Hamilton Times, Jan. 9 & 10, 1911
1912	Spearing poor - only a few sunfish and perch	Hamilton Harbour	Hamilton Times, Jan. 12, 1912
1922	Fishing poor	Hamilton Harbour	Hamilton Spectator, Nov. 30, 1923
1923	Dynamiting and jack lighting rapidly killing off sport fish	Hamilton Harbour	Hamilton Spectator, Nov. 23, 1923
1924	Pike and jumbo herring biting well	Hamilton Harbour	Hamilton Spectator, July 30, 1924
1943	in last 15 years ice fishing has died out	Hamilton Harbour	Students of Burlington Beach Bungalow School (1943 cited in Whillans 1977)
1948	Angling is good	Valley Inn area of Hamilton Harbour	Turner (1948)
1950	Better species of sporting fish no longer found - mostly carp and catfish caught	Hamilton Harbour and Cootes Paradise	Warren (1950)

Table 3. (continued)

Year	Abundance	Location	References
1970	no open water sport fishing - rainbow trout caught in tributary streams - isolated warm-water fisheries of local nature	western Lake Ontario including Hamilton Harbour	Weir, June 12, 1970
1973	smelt is major sport fishery in the spring	on the Lake Ontario side of Hamilton Beach and at the ship canal	Acres Consulting Services Ltd. (1973)
1979	Pacific salmon fishing is good occasional lake and brown trout are taken	off the docks at the entrance of the Burlington ship canal	Knap (1979)

Whillans (1977) estimated that a good fisherman could take 125-150 pounds of fish home per month. Assuming a three month winter period the annual harvest was approximately 3.0×10^3 kg. About one sixth was bass and the rest was pike (Kerr and Kerr, Jan. 5, 1891; Hamilton Herald, Jan. 29, 1892). A major controversy erupted in 1891 concerning the destructive effects spearing had on black bass (Kerr and Kerr, Jan. 24, 1891). An investigation by E.E. Prince found that five out of six fish speared escaped seriously injured. Thus the annual fishing mortality was probably about 1.8×10^4 kg (Citizens of the City of Hamilton c. 1895 cited in Whillans 1977).

Most of the spearing occurred in the northwest corner of the harbour. Around 1900 about 100 huts could be seen there (Kerr and Kerr, Nov. 23, 1895; Halcrow 1970). Smaller congregations of ice huts could be found close to the beach near Windermere Basin and in Cootes Paradise (Kerr and Kerr, Dec. 28, 1864; Dec. 14, 1865). Angling around the shoals along the southern shore was a common practice during the summer (Halcrow 1970) (Table 3).

By 1911 large quantities of carp and pike were being caught but the popularity of spearing had not diminished appreciably. A 1912 picture shows 59 huts in a small area of the harbour (Hamilton Evening Times, Jan. 29, 1912). Shortly afterwards sport fishing began to decline but the effects did not become remarkable until the early 1920's (Table 3). Dynamiting and jack lighting were blamed by anglers for the rapid decline in sport fish (Hamilton Spectator, Nov. 23, 1923).

In 1921 and 1922 black bass and walleye stocking in the harbour were initiated by anglers (Hamilton Spectator, May 30, 1922). In 1927 anglers tried to get a ban on commercial fishing enforced (Hamilton Spectator, March 8, 1927). Ultimately both efforts were unsuccessful.

In the late 1920's and early 1930's spearing collapsed followed in the 1940's by the summer fishery (Stud. Burl. Bea. Bung. School 1943; Smith 1976; both cited in Whillans 1977; Warren 1950) (Table 3). Currently there are isolated sport fisheries of a local nature in the vicinity of the harbour (Weir, June 12, 1970). The spring smelt run is the major sport fishery (Acres 1973). Occasionally coho and chinook salmon and the odd lake trout and brown trout are caught off the docks at the entrance to the Burlington ship canal (Knap 1979). There is some pan fish angling in Cootes Paradise at present although its extent is unknown (Whillans 1977).

4. ABIOTIC CHANGES

4.1 BATHYMETRY AND DREDGING

This section is a brief examination of the bathymetric and dredging history of the harbour. Whillans (1977) provides a more detailed review.

Historic information on the bathymetry of the harbour is scarce for the period before the turn of the century (Fig. 14). A comparison of 1915 maps (see Whillans 1977) and the 1975 map (Fig. 14) shows that most of the changes have been confined to the middle of the outer basin and along the south and east shores. The maximum depth of the outer basin has been increased from 21 to 24 m and dredging has deepened the south and eastern shores. The difference in maximum depth is likely due to differences in survey methods.

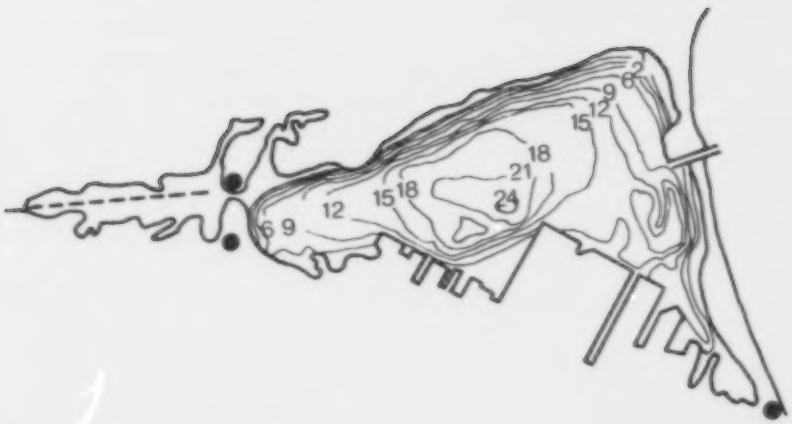
Kay (1949) was the first to publish comprehensive bathymetric information on Cootes Paradise. At that time the marsh was said to be filling in from west to east. The deepest area was 2 m in the open water at the east end.

By comparison, reasonably good information on the history of dredging in the harbour is available. Dredging was first undertaken with the construction of the Desjardins Canal through Cootes Paradise and around the north end of the Burlington Heights between 1826 and 1833 (Ozanian 1957). Between 1851 and 1854 a cut was made through the Heights necessitating the dredging of a new channel (Kerr and Kerr, Dec. 14, 1885). Whillans (1977 in Appendix XI) has summarized the dredging activities in the harbour from 1898

1865

Source: Maitland (1862) taken from Whillans (1977)

1975



Source: Can. Hydrogr. Serv. (1976), Lord (1971) taken from Whillans (1977)

Fig. 14. Hamilton Harbour bathymetry, 1865 and 1975. Depth contours are in meters.

to 1972. Most of these activities were undertaken along the southern shore around Eastwood Park, Stelco and Dofasco. Dredging activity peaked between 1951 and 1962 when 4.7 million cubic yards of material was removed (Whillans 1977).

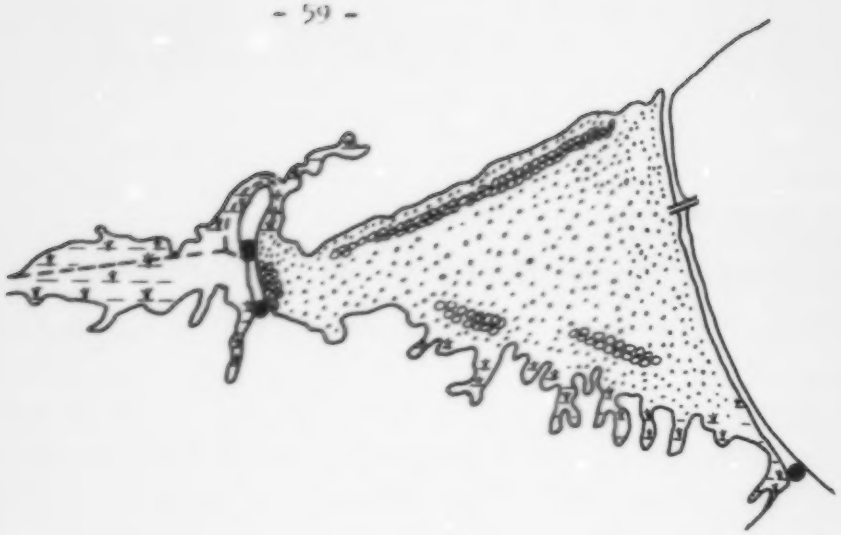
Some channelization of the Burlington ship canal was done in 1895 but the resulting dimensions of the canal are unknown (Kerr and Kerr, Dec. 3, 1895). Between 1926 and 1969 the dimensions of the canal doubled from 44 m wide x 5.4 m deep to 88 m wide x 9.6 m deep (Dick and Marsalek 1973). Exchange flow between the harbour and Lake Ontario has probably been significantly influenced as a result. This may have important implications for rehabilitation in the harbour.

4.2 BOTTOM MATERIALS

Substantial changes have occurred in the composition of the bottom materials in Hamilton Harbour. Historically much of the bottom was composed of fine sand materials (Fig. 15). A gravel and sand bottom was found along the beach south of the ship canal for a distance of 2 miles and for one mile along the Heights at the western end of the harbour (Kerr and Kerr, Jan. 26, 1874). Along the north shore an extensive bar of sand and gravel stretched between Carroll's Point and the northeast corner and two more, 1-2 miles long and 400-600 yards wide were found 500 yards off of the south shore (Kerr and Kerr, Jan. 26, 1874). Less than a tenth of the bottom was mud.

Most of Cootes Paradise, the northwest and northeast corners of the harbour and many of the inlets along the southern shore had predominately organic bottom materials.

1865



Source: Maitland (1862), Kerr and Kerr (Jan. 26, 1874) taken from Whillans (1977)

1975

stone, rock, gravel

coarse sand, sand, hard sand

silt-sand, fine sand

mud, silt, clay-silt

organic, marsh

Source: Can. Hydrogr. Serv. (1976), Lord (1971), Miller and Szewczyk (1971) taken from Whillans (1977)

Fig. 15. Changes in the bottom materials of Hamilton Harbour, 1865-1975.

Whillans (1977) indicates the key period of change was 1865-1915. By 1975 little was left of the historic bottom materials (Fig. 15). Mud, silt and clay were the predominant substrate, although two areas of sand are apparent. Organic material was found in a thin strip along the north shore, the northwestern corner and in most of Cootes Paradise.

The current evidence does not indicate the fate of the historic bottom materials. The gravel and sand bars along the southern shore have probably been lost. However, there is a good possibility that the gravel bar along the north shore and much of the sandy material elsewhere are still present, buried under silt and mud. Pronounced population growths from 1901 to 1931 and again from 1941 to 1971 correspond with increased siltation in the harbour and inflowing tributaries.

5. OTHER BIOTIC CHANGES

5.1 AQUATIC MACROPHYTES

Aquatic macrophytes are an important component of the Hamilton Harbour ecosystem. In addition to converting nutrients into food for other types of aquatic life such as waterfowl and muskrats, they also provide spawning, nursery and feeding sites for fish (Jaworski and Raphael 1979; Simser 1982).

Good information on macrophytes generally does not exist prior to the late 1940's. However because wild rice, Zizania aquatica, was an important foodstuff some early observations were recorded. In 1820 Z. aquatica was widespread in Cootes Paradise (Holden 1899). For the next century it remained "... so abundant, that in rowing through the marsh, one's boat would be covered with rice" (Wragg 1949). Heavy siltation and the damaging effects of carp, C. carpio, resulted in the disappearance of Z. aquatica by the early 1940's (Lamoureaux 1958). Decreased water levels in 1930 may also have had an adverse impact (Whillans 1977). In the late 1940's and early 1950's attempts were made to reinstate Z. aquatica. Success was achieved in 1955 and by 1958 wild rice was one of the dominant emergent macrophytes again (Lamoureaux 1958). Its present status is unsurveyed.

Early maps from 1789, 1821 and 1823 show extensive marsh areas along the south, east and northeast shores of the harbour (Anonymous 1789; Marlet 1821; Dumfrie 1823). A map by Ford (1836) also shows extensive marsh vegetation along the western and northwestern shores. These areas supported large macrophyte communities which included bulrushes Scirpus sp., and sedges (Kerr and Kerr, Oct. 13, 1873).

The vegetation in the northeast corner of the harbour was removed by the construction of a small canal to Lake Ontario in 1876 (Kerr and Kerr, Aug. 7, 1876). It apparently regenerated because in 1902 vegetation was removed from this area again (Ham. Harb. and Beach Comm., Aug. 20, 1902 cited in Whillans 1977).

Along the south shore the development of the Hamilton waterfront and associated shoreline restructuring and landfilling which began in 1909 (Ozanian 1957) drastically reduced the vegetation. The cattail marsh at the mouth of Redhill Creek is all that remains of the once extensive marsh in this area (Ont. Min. Trans. Comm. 1982).

Intensive studies of Cootes Paradise by McMaster University and the Royal Botanical Gardens began in the late 1940's. Detailed inventories of the aquatic macrophytes were compiled which show that the species composition and abundance of the submergent and floating-leafed macrophyte communities were considerably altered by the early 1970's. Kay (1949), Wragg (1949) and Judd (1950) recorded 10 families, 13 genera and 24 species of submergent and floating-leafed macrophytes in the marsh. Dominant genera included Ceratophyllum, Myriophyllum, Utricularia and Elodea (Table 4). Bidens cernua and Nymphaea became dominant taxa by 1953 (Tamsalu 1953). Surveys made between 1968 and 1972 found only 5 families, 8 genera and 10 species of submergent and floating-leafed macrophytes in Cootes Paradise. Potamogeton pectinatus, Lemna and Nymphaea tuberosa were dominant taxa (Table 4). Several species including P. natans, Myriophyllum verticillatum var. punctatum and Nuphar advena disappeared in the intervening twenty years while others such as P. crispus, L. minor and Spirodela polyrhiza remained relatively unchanged.

Table 4. Checklist of submergent aquatic plants in Cootes Paradise

Taxon	1946-1948	1968-1972
Potamogeton berchtoldii	1	-
P. crispus	2	2
P. foliosus var. macellus	1	-
P. natans	1	-
P. nodosus	2	1
P. pecinatus	2	3
P. perfoliatus	1	-
P. zosteriformis	2	-
Najas flexilis	1	-
Elodea canadensis	2	1
Spirodela polyrhiza	1	1
Lemna minor	3	3
L. triscula	1	-
Wolfiia columbiana	1	1
W. punctata	1	-
Polygonum amphibium var. stipulaceum	2	-
Ceratophyllum demersum	3	2
Nuphar advena	3	-
N. variegatum	3	2
Nymphaea odorata	3	-
N. tuberosa	3	3
Myriophyllum verticillatum var. punctatum	3	-
Utricularia vulgaris	3	1
Megalodonta beckii	1	-

Key - 3 - plants in large numbers and dominant at a few or many sites;
2 - plants which are not dominant but which are occasionally or frequently encountered;
1 - not common or dominant, collected once or twice;
- - plants not encountered.

Source: Lord (unpublished) taken from Simser (1982)

The emergent macrophyte community also underwent substantial changes during the same period. Kay (1949), Wragg (1949) and Judd (1950) indicated the dominant species were Glyceria maxima and Typha latifolia. Glyceria maxima occupied slightly more area than T. latifolia. A reduction in the area of emergent vegetation began in 1946-1947 and continued until 1953 (Whillans 1977). By 1971 emergent macrophytes had regained much of their former status although the species composition was different (Whillans 1977). Glyceria maxima and T. latifolia were still the dominant emergents.

The aquatic macrophyte community has been affected by fluctuations in water levels and nutrient enrichment. High water levels in 1953 caused the reduction of many emergent species (Lord 1976 cited in Whillans 1977). During the early 1960's low water levels probably caused reductions in Nuphar advena, Nymphaea odorata, C. demersum and M. verticillatum var. punctatum and a revival of G. maxima and T. latifolia by the early 1970's (Whillans 1977). The disappearance of P. foliosus var. macellus and Najas flexilis by the mid-1960's indicates the presence of nutrient enrichment because these species would normally be expected to increase with the lower water levels of that period (Whillans 1977).

Carp, which have been numerous in the marsh since 1935 (Lamoureaux 1958), have also had an impact. Their uprooting actions have limited the growth of Z. aquatica in the past. Both Potamogeton pectinatus and P. crispus, which were abundant in 1972, are extremely resistant to the uprooting actions of carp (King and Hunt 1967 cited in Simser 1982).

The marsh community in Hamilton Harbour has lost approximately 340 ha or 74% of its area in the last 150 years (Whillans 1982). This has been aggravated by a decline in the quality of the surviving marsh (Table 4) and has resulted in substantial losses of fish and wildlife habitat. A similar situation has been observed by Jaworski and Raphael (1979) along the United States shoreline of the Great Lakes.

The changes in aquatic macrophytes are reasonably well documented prior to 1972. Further changes have probably occurred since then, however, records do not exist to confirm this fact.

5.2 PLANKTON

Studies conducted in 1948-49 and 1975 reveal that a shift in the dominant plankton taxa in the harbour has occurred. Dominant phytoplankton taxa common to the harbour and marsh in 1948-49 included Chlorophyceae Scenedesmus and Pediastrum; and diatoms such as Synedra ulna, Asterionella and Fragillaria and in Cootes Paradise the blue-green algae Aphanizomenon (Sims 1949; Matheson 1958). Predominant zooplankton species included cladocerans such as Bosmina (and Daphnia in the marsh), rotifers such as Annurea, Polyarthra and Keratella and occasionally, the protozoan Euglena (Kay 1949; Matheson 1958). In 1975 Chlorophyceae such as Oocystis, Coelastrum, Selenastrum and Pandorina morum were dominant during the summer months and diatoms such as Stephanodiscus, Cyclotella and Synedra ulna were dominant during the fall (MOE 1977). Protozoans such as Euglena, Cryptomonas and Rhodomonas were also observed.

The changes observed between these studies are generally indicative of increased nutrient enrichment in the harbour and Cootes Paradise (Bacchus 1974; Wetzel 1975; MOE 1974 cited in Whillans 1977). Normally, as nutrient enrichment increases blue-green algal taxa such as Aphanizomenon and Anabaena and euglenophytes such as Euglena would be expected to dominate the phytoplankton community (Wetzel 1975). The lack of blue-green algae in the harbour in 1975 was attributed to the physically unstable water column (MOE 1977). Phytoplankton production did not appear to be nutrient limited although there was some evidence of light limitation and zinc toxicity (MOE 1977).

5.3 BENTHIC INVERTEBRATES

Historically whitefish were known to immigrate into Hamilton Harbour during June and July to feed on small shellfish (probably sphaeriids) and deepwater "shrimp-like" organisms (probably Ponteporeia affinis) (Kerr and Kerr, Nov. 8, 1872; July 4, 1874; Whillans 1977). Ponteporeia affinis became scarce in 1880 and during the fishing season the fishermen at Hamilton Beach reported that the ciscoes were "lean, thin and in bad condition" (Kerr and Kerr, Feb. 16, 1880). By 1882 whitefish had partially switched their diet to small fish (Kerr and Kerr, April 17, 1882).

Turner (1948) reported that invertebrates such as snails, crustaceans and crayfish were abundant in Cootes Paradise. These organisms were preyed upon by sunfish, bullheads, mudminnows and yellow perch.

In 1964-65 Johnson and Matheson (1968) found that the profundal sediments of the harbour contained an abundance of oligochaetes in densities

varying between 70 worms/m^2 and 22,600 worms/m^2. Limnodrilus hoffmeisteri and Tubifex tubifex were the dominant species. They were generally most abundant throughout the main basin and the western end. They were least abundant in the northeastern part of the bay where the sediments were predominantly sand. Small numbers of chironomids were found along the northern shore. No benthic invertebrates were found in approximately 2 km^2 of sediments near the steel plants.

The last survey in 1972-73 (MOE 1974 cited in Whillans 1977) found that oligochaete abundance had increased over a larger area and that the area in which no invertebrates existed had also increased.

Judd (1949a; b) collected emerged insects from the vegetation in and around Cootes Paradise between 1946 and 1948. Mayfly nymphs, chironomid larvae and caddisfly larvae were abundant (Turner 1948). Whillans (1977) points out that the complete absence of Hexagenia is an indication that there may be organic pollution in the marsh.

The changes that appear to have taken place in the benthic invertebrates are indicative of environmental degradation. The disappearance of P. affinis in 1880 suggests the presence of organic pollution in the harbour. Johnson and Matheson (1968) found P. affinis just outside the harbour in Lake Ontario in 1964 and 1965. The dominance of L. hoffmeisteri and T. tubifex in the harbour sediments is evidence of further degradation in water quality due to organic pollution. The complete absence of invertebrates near the steel mills suggests heavy chemical pollution or complete anoxia.

6. HABITAT CHANGES

The availability of a variety of physical habitat types is essential to the functioning of a healthy fish community. Many species, for instance walleye, utilize distinctly different habitats for feeding, rearing and spawning. For other species the use of a particular habitat may vary diurnally (i.e. alewife), seasonally (i.e. smallmouth bass) or with various stages in the life history (i.e. Atlantic salmon).

The habitat in Hamilton Harbour can be operationally divided into three classes: (1) openwater pelagic, (2) profundal, and (3) littoral or nearshore. Each is characterized by a distinct assemblage of fish species. The openwater pelagic and the profundal habitats are relatively small and confined to the central area of the outer basin. The littoral habitat is extensive, extending well offshore along the southern and western shores of the outer basin and encompassing all of Cootes Paradise.

The historic and current distributions of species characteristically associated with the different habitat types were documented (Figs. 16 to 23) in order to analyse habitat changes and their impact on the fisheries. Spawning areas, summer and winter habitat were delimited as accurately as possible. However, in many instances early historic observations are either scarce or vague with respect to the location and use of particular habitats. Spawning and habitat requirements were taken from Scott and Crossman (1973), Whillans (1977) and Christie (1982). These combined with observations on presence were used to compile the historic distributions. Netting data from the Ontario Ministry of Natural Resources (1975; 1976) and the Royal Botanical Gardens (1978) were used to compile the current distributions.

Because of the highly mobile and opportunistic nature of fish, changes should be expected in their distribution as the environment is altered. See Appendix I for sources for each Figure.

6.1 PROFUNDAL HABITAT

Lake trout S. namaycush and lake whitefish C. clupeaformis were characteristic of the profundal habitat in the harbour. Their distributions during the summer and winter were restricted, reflecting the limited availability of profundal habitat historically (Figs. 16 and 17). There is no evidence that S. namaycush ever spawned in the harbour. However, C. clupeaformis was known to spawn along the beach (Kerr and Kerr 1860-1898) and may also have utilized sand and gravel bars along the north and south shores (Fig. 17).

The current evidence indicates that there is still profundal habitat in the harbour (Fig. 14) yet both species are non-existent. Increased siltation as a result of a pronounced growth in human population from 1901 to 1931 (Whillans 1977) almost certainly had an undesirable impact. The preferred substrate of both species and the inshore spawning areas of C. clupeaformis were probably smothered as a result (see Fig. 15 and Section 4.2). The fact that both species were not extirpated in the harbour until the early or mid-1930's suggests that another stress was involved. Thus deteriorating water quality due to organic pollution from sewage and industrial effluents was and probably still is the most important factor limiting the availability of profundal habitat.

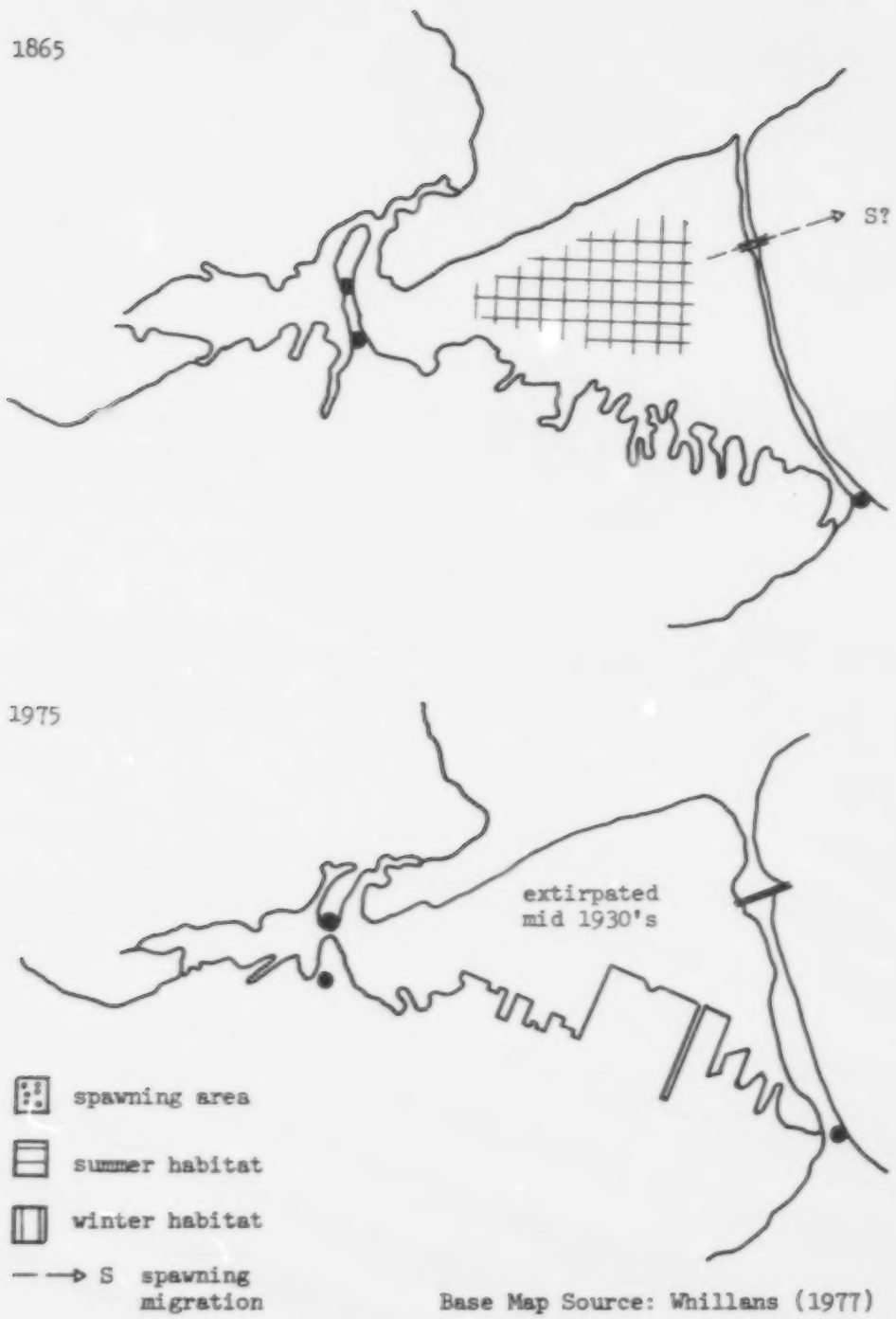


Fig. 16. Changes in the distribution of Salvelinus namaycush in Hamilton Harbour.

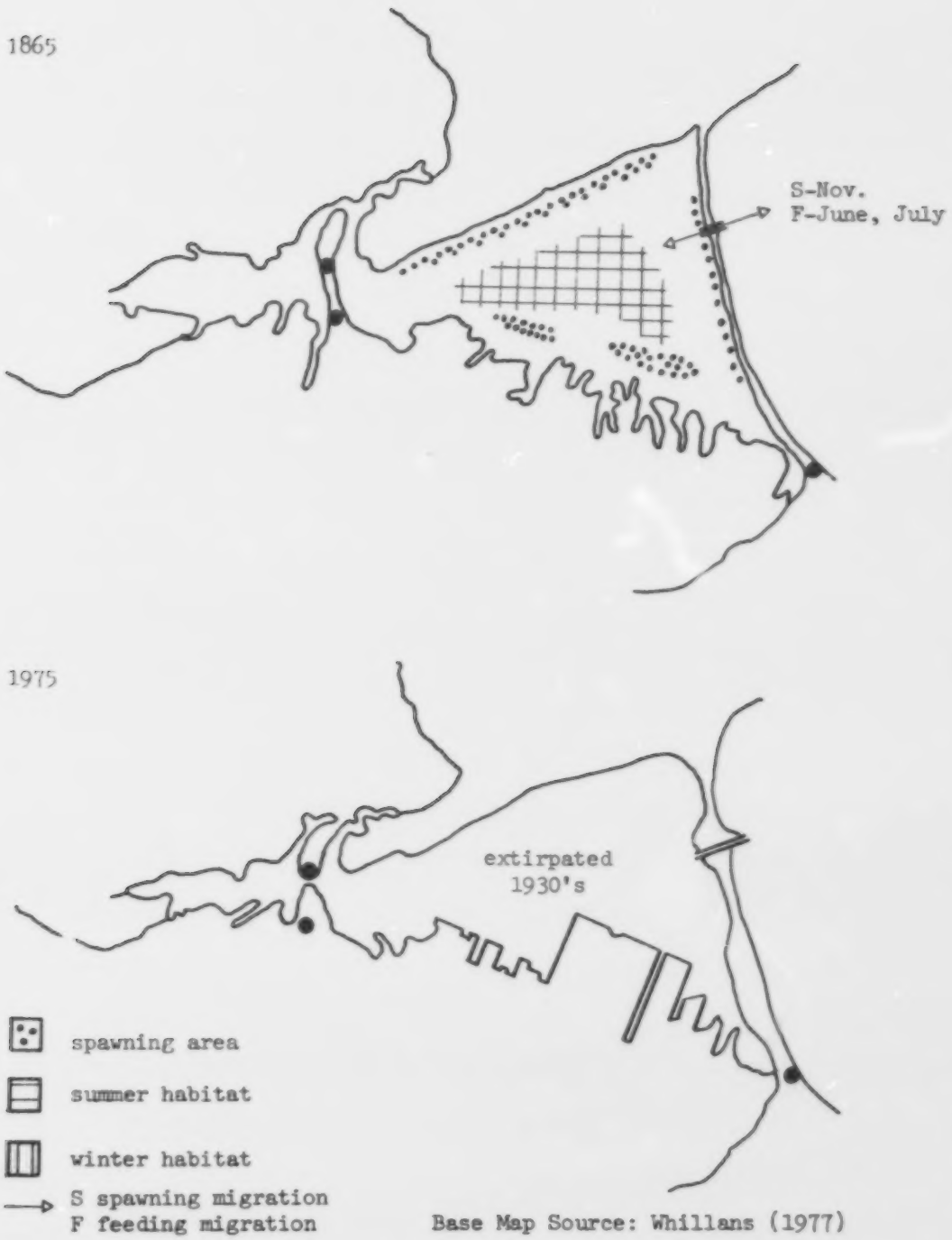


Fig. 17. Changes in the distribution of Coregonus clupeaformis in Hamilton Harbour, 1865-1975.

Early observations reveal that for the most part pollution from industrial effluents was restricted to Cootes Paradise and the inlets along the southern shore of the harbour (Kerr and Kerr 1860-1898). The scarcity of P. affinis beginning in 1880 is the first indication of more widespread effects (Kerr and Kerr, Feb. 16, 1880). The construction of collector sewers from Hamilton in 1888 caused noticeable damage to the fish and fisheries (Kerr and Kerr, March 6, 1888). Water quality continued to decline thereafter until the 1960's.

Matheson (1958) found that the harbour sediments contained "enormous" quantities of organic material largely derived from sewage disposal. He concluded that the harbour would not be deleterious to fish and other aquatic life because large amounts of dissolved oxygen were always present and the constant circulation of the water would prevent any serious depletion. His oxygen data show that much of the hypolimnion had low dissolved oxygen levels throughout the summer months. In August the water below 4 m had less than 5 mg/L of dissolved oxygen, which is generally considered to be a minimum requirement for fish. Thus any deepwater fish in the harbour would be severely restricted by these conditions.

Toxic events, contaminants and other components of water chemistry have probably contributed directly and indirectly to the restricted availability of profundal habitat in the harbour. PCB's, heavy metals and organic compounds residing in the sediments exert a tremendous oxygen demand resulting in the establishment of anoxic conditions in the deepwater soon after stratification (MOE 1977; 1978). Water chemistry data have been

evaluated by Matheson (1958) and Tomlinson et al. (1971). The effects of alterations in various water chemistry elements (i.e. ammonia) was probably minor. Nevertheless they are included for completeness.

Presently there is potentially ample profundal habitat in the harbour. However, this habitat is unavailable to desirable deepwater species such as lake trout and whitefish because of inadequate dissolved oxygen. Re-establishing the historical utilization of the profundal habitat will depend largely on the availability of adequate dissolved oxygen levels on a year round basis. The extremely localized effects of aeration experiments in the mid-1970's (MOE 1977; 1979) suggest that to achieve an increase in oxygen levels will be difficult from a practical standpoint.

6.2 OPENWATER PELAGIC HABITAT

Herring, primarily C. artedii but also other Coregonus species were characteristic of the openwater pelagic habitat historically. Summer habitat and spawning areas in the harbour (Fig. 18) were probably much broader in extent than those of either S. namaycush or C. clupeaformis (Figs. 16 and 17).

As with the profundal habitat, the current evidence indicates that there is still openwater pelagic habitat in the harbour (Fig. 14). Deteriorating water quality, which at first restricted and then eliminated the availability of profundal habitat by the 1930's, probably had the same effect on the openwater pelagic habitat (Fig. 18). The dominance of alewife in the harbour since the late 1870's (Kerr and Kerr, Feb. 8, June 23, 1877)

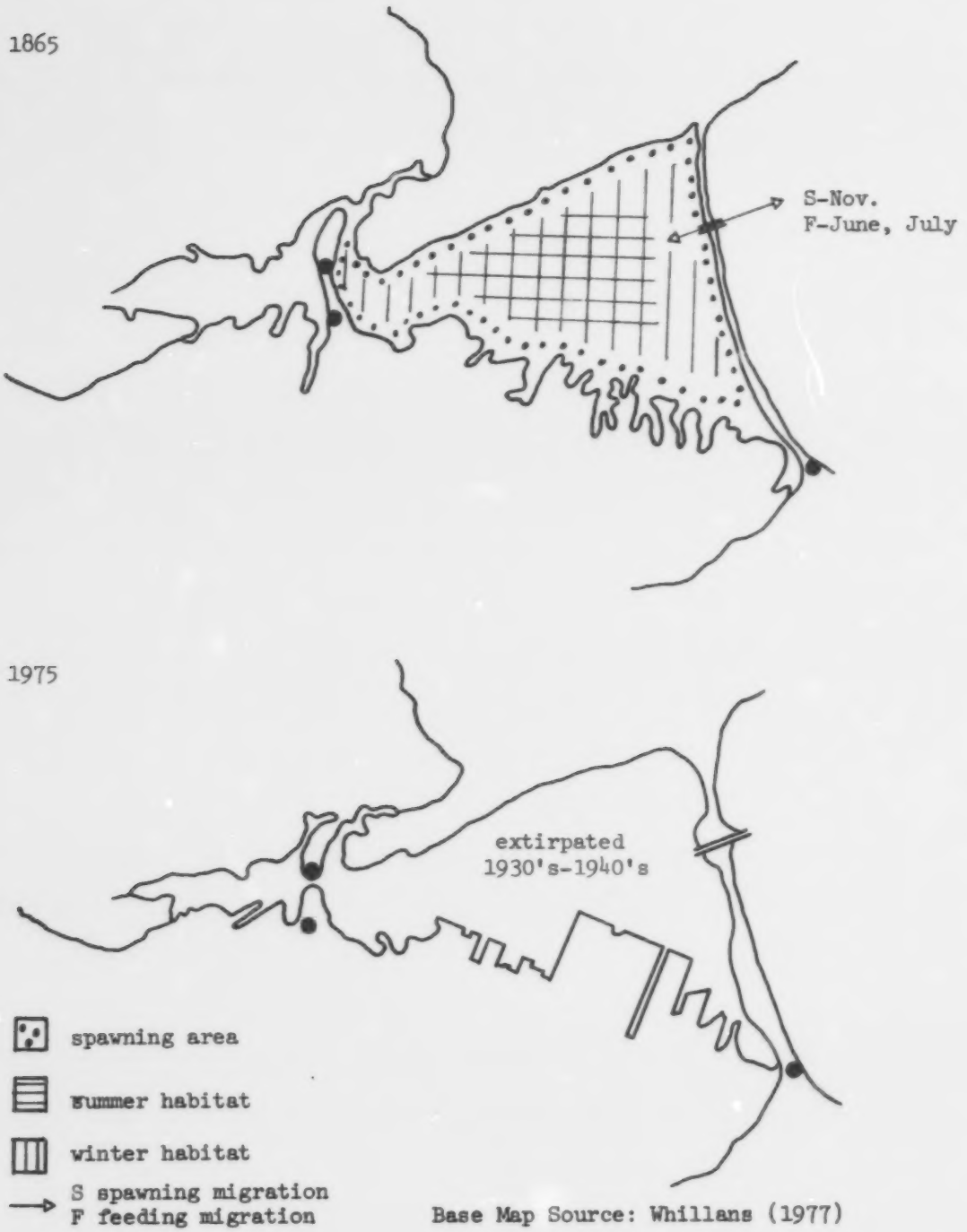


Fig. 18. Changes in the distribution of Coregonus artedii and Coregonus sp. in Hamilton Harbour, 1865-1975.

and the large increase in herring abundance by the turn of the century (Fig. 4) suggest that the effects of poor water quality were delayed and may not have been as severe in the openwater pelagic habitat as in the profundal habitat.

Although there is probably a small amount of pelagic habitat presently available above the thermocline (utilized by alewife), high temperatures prevent its utilization by more desirable pelagic species such as herring.

There is a substantial amount of openwater pelagic habitat in the harbour at present. But its availability to desirable species is prevented by low levels of dissolved oxygen or anoxia soon after stratification. Thus until adequate dissolved oxygen levels are achieved the utilization of this habitat by fish will not occur.

6.3 LITTORAL HABITAT

The littoral habitat includes open nearshore and marsh areas. Fish taxa in the harbour characteristic of this habitat include *E. lucius* and *E. masquinongy* (Fig. 19), *M. dolomieui* and *M. salmoides* (Fig. 20), *P. flavescens* and *S. vitreum* (Fig. 21), *Catostomus* sp. and *Moxostoma* sp. (Fig. 22) and *C. carpio* (Fig. 23). All are or were permanent residents in the harbour and Cootes Paradise and many make extensive use of littoral spawning areas. *Cyprinus carpio*, *P. flavescens* and *S. vitreum* utilize other habitats in the harbour but are included here because they are more dependent on the littoral habitat for survival.

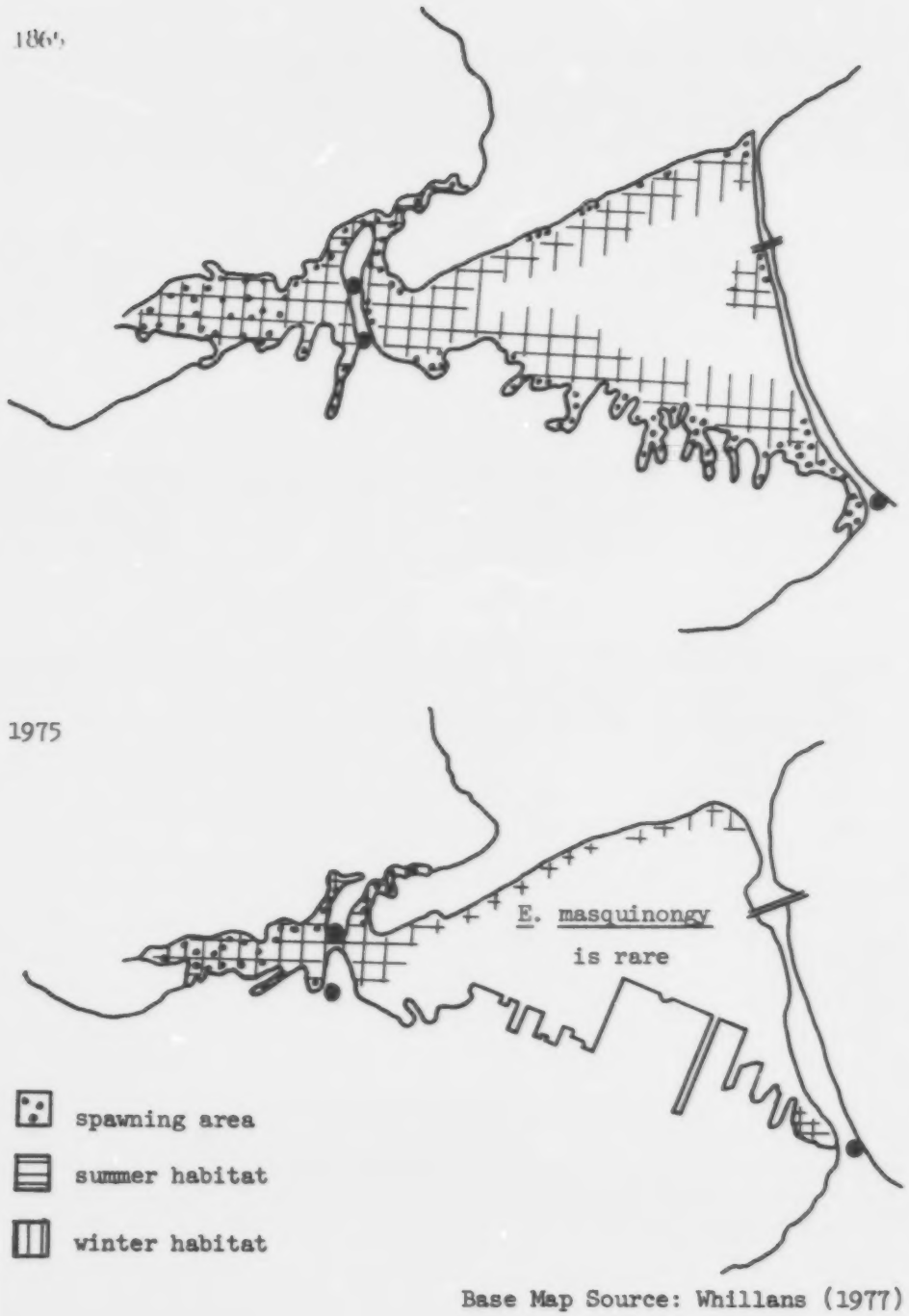


Fig. 19. Changes in the distribution of Esox lucius and E. masquinongy in Hamilton Harbour, 1865-1975.

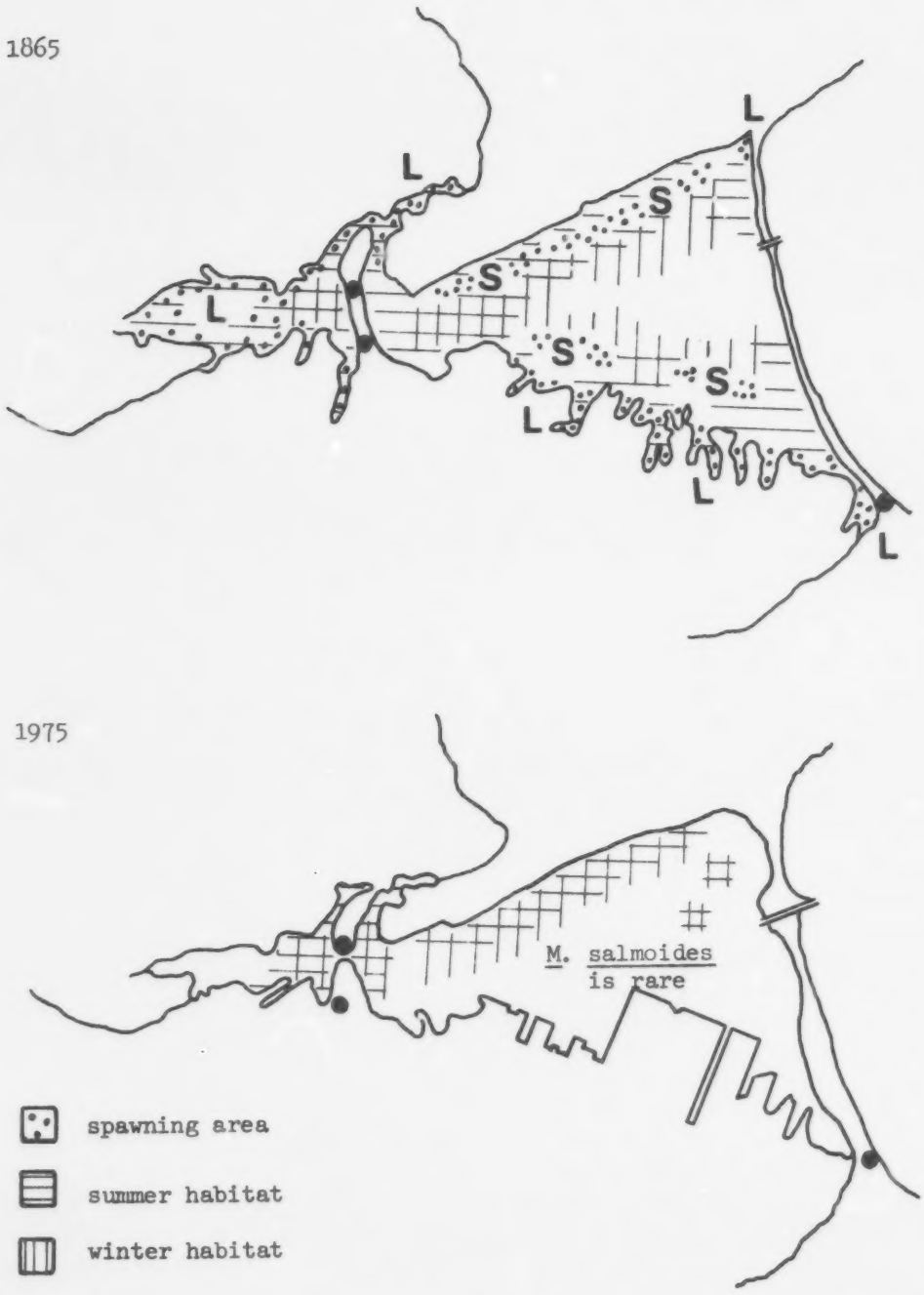


Fig. 20. Changes in the distribution of Micropterus dolomieui and M. salmoides in Hamilton Harbour, 1865-1975.
L -Largemouth Bass; S -Smallmouth Bass.

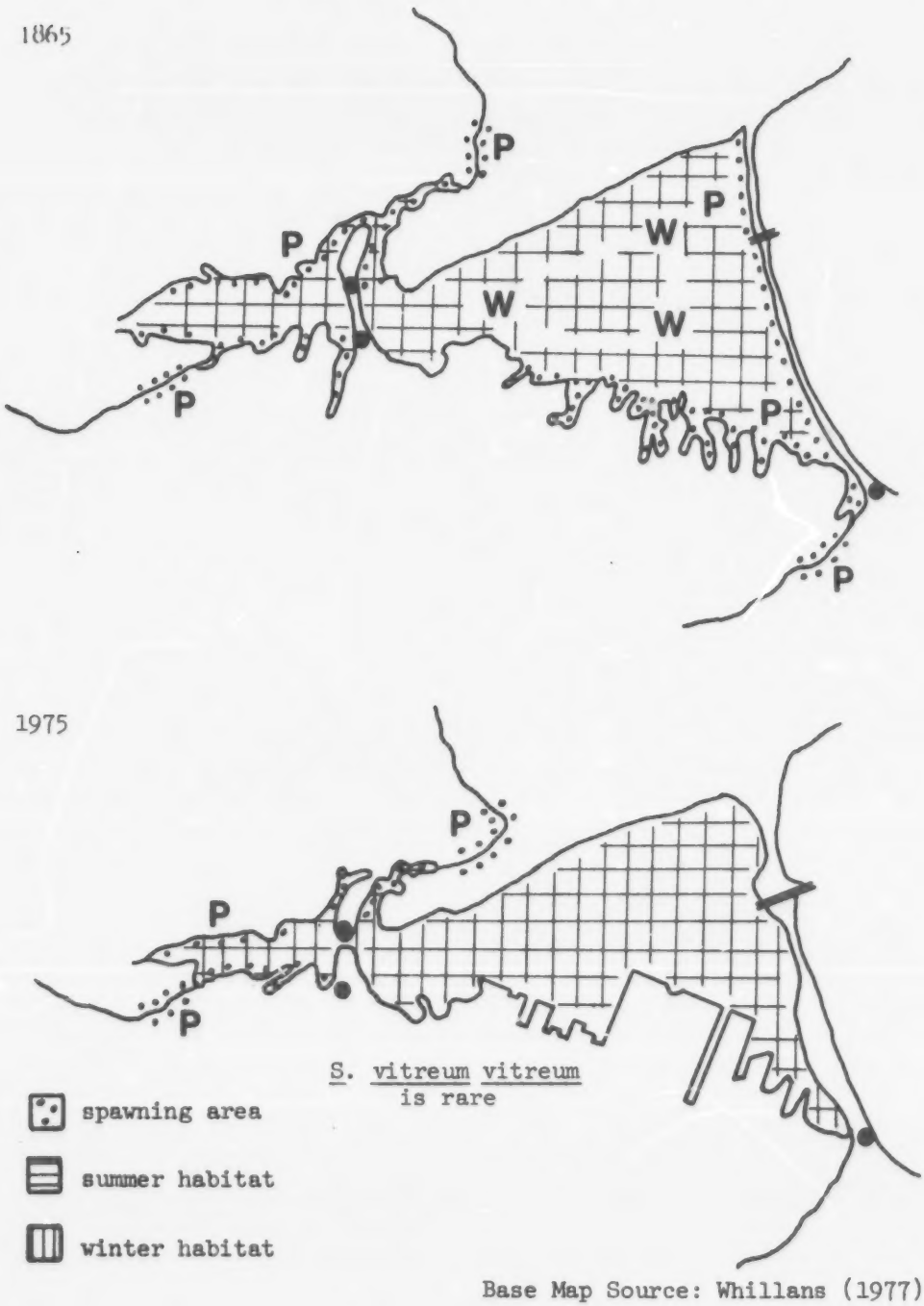


Fig. 21. Changes in the distribution of Perca flavescens and Stizostedion vitreum vitreum in Hamilton Harbour, 1865-1975.
P -Yellow Perch; **W** -Walleye.

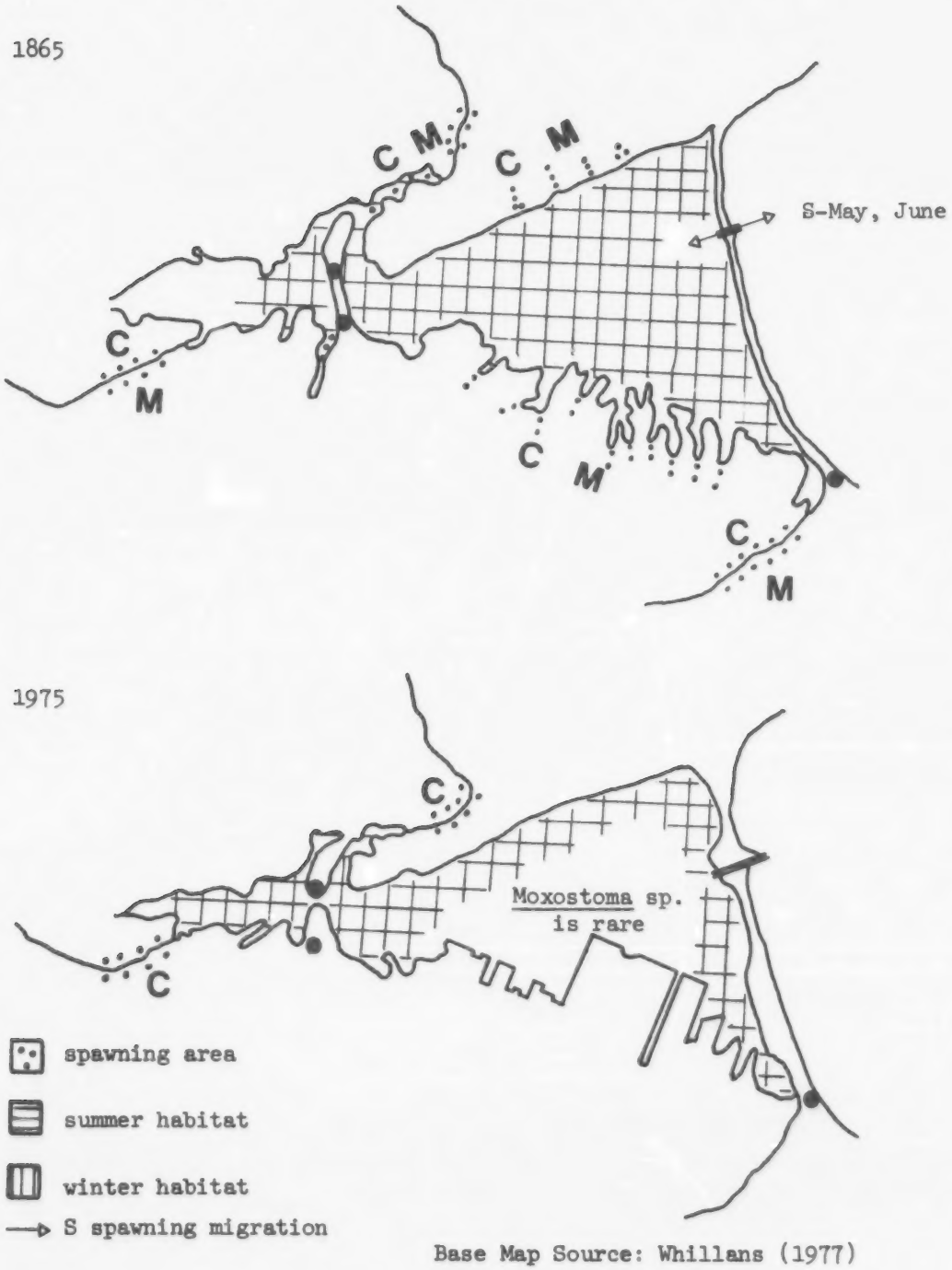


Fig. 22. Changes in the distribution of Catostomidae (Catostomus sp. and Moxostoma sp.) in Hamilton Harbour, 1865-1975.
C -Catostomus sp.; **M** -Moxostoma sp.

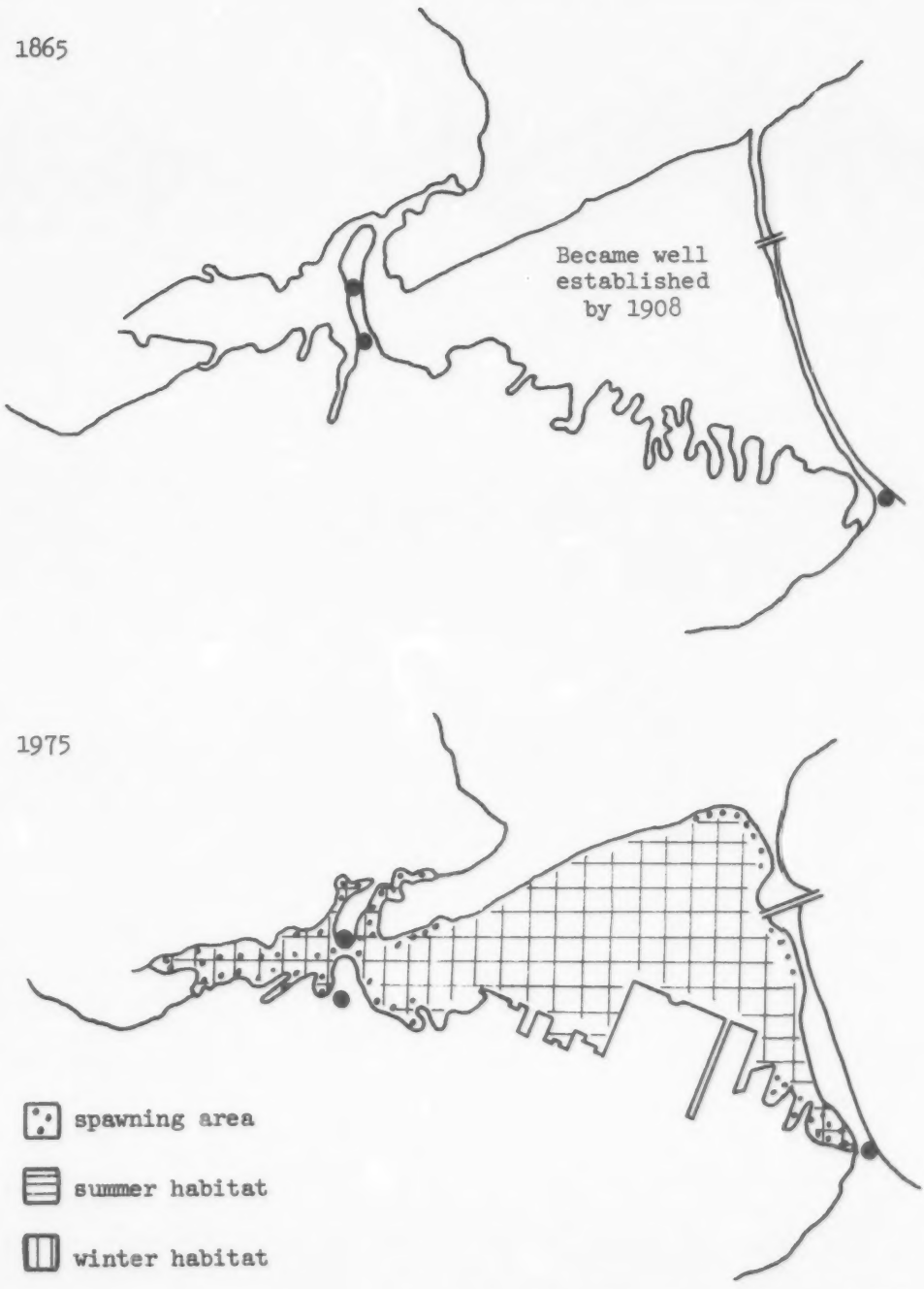


Fig. 23. Changes in the distribution of Cyprinus carpio in Hamilton Harbour, 1865-1975.

Of the three habitat types in the harbour the littoral habitat has undergone the most dramatic changes. Between 1845 and 1979, 340 ha or 74% of the marsh was lost (Whillans 1982). Most of this was along the southern shore of the harbour where extensive mechanical restructuring has occurred since 1909 (Ozanian 1957). Landfilling activities seriously reduced shallow nearshore areas at the same time. Increased siltation from 1901 to 1931 and again from 1941 to 1971 probably aggravated the physical disruption of littoral and marsh habitat.

The outcome of these activities is evident from the distribution of fish in the harbour. Taxa such as E. lucius and E. masquinongy (Fig.19), M. dolomieui and M. salmoides (Fig. 20), S. vitreum (Fig. 21) and Catostomus sp. and Moxostoma sp. (Fig. 22) which utilized littoral habitat for spawning, rearing and feeding have had their distribution substantially reduced. Many of these species, if they are present in the harbour, probably utilize the north and western shores where comparatively little habitat has been lost although the lack of a sand and gravel substrate at present probably represents a loss in quality (Fig. 15).

Cyprinus carpio (Fig. 23) and probably P. flavescens (Fig. 21) are widespread in the harbour at present. For C. carpio this reflects an ability to tolerate enriched environmental conditions (Scott and Crossman 1973) and utilize degraded habitats much more successfully than traditionally desirable species such as smallmouth bass.

Changes have also occurred in Cootes Paradise. Infilling of unknown extent has taken place (Kay 1949). More important however, is the decline in quality of the surviving marsh (see Sect. 5.1, Table 4). The decline of M. salmoides (Fig. 20) and the abundance of C. carpio (Fig. 23) is an indication of the shift in quality that has occurred. An extended summer bloom of algae in the West Pond and main open water area in 1974 (Bacchus 1974) is another indication of a decline in marsh quality.

There is direct evidence that extensive littoral habitat has been lost in the harbour (see Fig. 15). In the past both the harbour and Cootes Paradise have functioned as sewage lagoons providing additional treatment before effluents moved out into Lake Ontario (Matheson 1958; Bacchus 1974). The current evidence suggests that this combined with extensive landfilling and other shoreline restructuring has substantially reduced the littoral habitat.

Jaworski and Raphael (1979) have argued that a decline in marsh quality is accompanied by significant losses in fish and wildlife. The current situation in the harbour and Cootes Paradise supports this argument.

Improving or increasing the amount of littoral habitat would probably have positive effects on most of the warmwater species presently found in the harbour (Table 5). The current evidence suggests that the lack of littoral habitat or its poor quality or both is limiting to warmwater fish. Studies during recent years have found that many species are making extensive use of the northern shore of the harbour where relatively high quality littoral habitat remains (V. Cairns, Jan. 11, 1984).

6.4 SUMMARY OF HABITAT CHANGES

There is probably no difference between the volume of profundal and openwater pelagic habitats in the harbour historically and presently. What is different is that today neither of these habitats is available to lake trout, whitefish or herring which historically utilized them. The major reduction of dissolved oxygen soon after stratification precludes their use. Thus if coldwater species are desired then the availability of these habitats will have to be improved. If this is accomplished it may also be beneficial to species such as S. vitreum which generally prefer deeper water than other warmwater species (Table 5).

In contrast both the quantity and quality of littoral habitat in the harbour and Cootes Paradise have been reduced. What remains is heavily utilized by many species of warmwater fish. Extensive shoreline restructuring, especially landfilling are major causes of the loss.

It is probable that increasing the amount of littoral habitat would be beneficial to many warmwater species. Quality improvements in the remaining habitat (i.e. increasing the diversity and quantity of desirable macrophytes, improved bottom substrate) could have similar results. These changes probably would be beneficial to herring and whitefish as well since historically they spawned in nearshore areas of the harbour (Table 5).

Table 5. List of fish species recorded in Hamilton Harbour with notes on ecological characteristics and present abundance. Adapted from Whillans (1977)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
Petromyzon marinus	lithophil, nest spawner & guarder	late spring	11.1-34.4	rivers, streams	Moderate depth lakes	rare
Acipenser fulvescens	lithopelagophil open substratum non-guarder	spring	13.0-18.0	rivers, rarely lake shoals	Benthic, large rivers, lakes <10 m	extirpated (common 1860's)
Lepisosteus osseus	Phytophil, open substratum non guarder	late spring		shallow weedy areas of lakes	weedy, large rivers, lakes <10 m	rare
Amia calva	Phytophil, nest spawner, guarder	spring	16.0-19.0	lakes, rivers - shallow and weedy	weedy, large rivers, lakes <10 m	rare (common 1890's)
Alosa pseudoharengus	Phyto-lithophil open substratum non guarder	late spring	15.6-22.2	beaches and ponds	pelagic, lake >10 m	abundant
Dorosoma cepedianum	Litho-pelagophils, open substratum non guarder	late spring early summer	17.2-22.8	ponds, lakes, large rivers	weedy, lakes <10 m	abundant
Coregonus alpenae	Pelagophil, open substratum, non guarder	fall		18.3-47.5 m depths Lake Michigan and Lake Huron	pelagic, lakes >10 m	extirpated
C. artedii	Litho-pelagophil open substratum non guarder	fall	5.0-3.3	lakes, shallows or pelagically	pelagic, lakes >10 m	rare (abundant 1900)

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
C. hoyi	Litho-pelagophil, open substratum, non guarder	winter		lakes-depths of 36-91 m	pelagic, lakes >10 m	extirpated
C. kiyi	litho-pelagophil, open substratum non guarder	late fall early winter	1.7-3.4	lakes-depths of 91.4-167.6m	pelagic, lakes >10 m	extirpated
C. nigripinnis	Pelagophil, open substratum, non guarder	late fall early winter		lakes - very deep	pelagic, lakes >10 m	extirpated
C. reighardi	Pelagophil, open substratum, non guarder	early spring	3.8-4.7	lakes - 250 m	pelagic, lakes <>10 m	extirpated
C. zenithicus	Pelagophil open substratum non guarder	fall		lakes depths of 37-73 m		extirpated
C. clupeaformis	lithophil, open substratum non guarder	late fall	7.8	lakes less than 7.6 m	gravel, sand, lakes >10 m	extirpated (abundant 1860-80's)
Prosopium cylindraceum	lithophil open substratum non guarder	fall	4.5	lakes - shallows river mouths	rivers, lakes all depths	extirpated
Oncorhynchus kisutch	lithophil broad hiders non guarders	fall		rivers, streams creeks	pelagic, lakes >10 m	rare

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
Salmo gairdneri	lithophil brood hider non guarder	late fall & early spring	10.0-15.5	small tributaries	rock, gravel, sand, streams, lakes >10 m	very low
S. salar	lithophil brood hider non guarder	fall	3.9	small tributaries	pelagic lakes >10 m	extirpated (abundant 1810-30's)
Salvelinus fontinalis	lithophil brood hider non guarder	late summer fall		shallow head-water streams	gravel, sand, streams, rivers, lakes <10 m	rare
S. namaycush	lithophil brood hider non guarder	fall	13.9-8.9	lakes - shoals	pelagic, lakes >10 m	rare, (common 1860's)
Osmerus mordax	lithophil open substratum non guarder	spring	8.9-18.3	streams	pelagic, gravel, sand, lakes >10 m	abundant
Hiodon tergisus	lithopelagophil open substratum, non guarder	spring		large, clear streams	streams, rivers, lakes <10 m	extirpated (low 1890's)
Umbra limi	phytophil, open substratum non guarder	early spring	12.8-15.6	shallow creeks and streams	mud, creeks, streams, ponds	rare
Esox lucius	Phytophil open substratum non guarder	early spring	4.4-11.1	weedy areas rivers, marshes bays	weedy, rivers, lakes <10 m	common (abundant 1800-70's)

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
E. masquinongy	phytophil open substratum non-guarder	spring	9.4-15.0	weeds flooded areas	weedy, rocky areas, rivers, lakes <10 m	rare (abundant 1860-70's)
Chrosomus eos	phytophil open substratum non-guarder	spring early summer		algal masses	mud - streams rivers, ponds, lakes <10 m	low
Clinostomus elongatus	lithophil open substratum non-guarder	spring	18	streams	streams - pools	low
Notemigonus crysoleucas	phytophil open substratum non-guarder	late spring - early summer	20.0	lakes - weedy areas	weedy areas - lakes <10 m	common
Notropis antherinoides	pelagophil open substratum non-guarder	late spring early summer	24.0	midwater	gravel, sand, mud, weeds - large rivers, lakes	common
N. cornutus	lithophil substratum choose guarder	spring	15.6-18.3	streams, lakes - shoals	streams, lakes <10 m	low
N. heterodon	phytophil open substratum non-guarder	spring			weedy areas - creeks, streams, ponds, lakes <10 m	rare
N. heterolepis	psammophil open stratum non-guarder	spring - summer		lakes, rivers	sand, mud, weeds-streams lakes <10 m	common

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
N. hudsonius	psammophil open substratum non-guarder	spring early summer		lakes - shoals	gravel, sand, mud, weedy - large rivers lakes	common
N. spilopterus	phytolithophil open substratum non-guarder	spring summer		rivers <5 m	gravel, sand - rivers, lakes <10 m	common
N. stramineus	psammophil substratum non-guarder	late spring - summer		lakes, large rivers - shallows	sand - rivers lakes <10 m	rare
N. volucellus	phytolithophil open substratum non-guarder	lake spring early summer			lakes <10 m	low
Pimephales notatus	speleophil nest spawner guarder	spring summer	20.0	streams, shallows	gravel, sand- streams, rivers ponds, lakes <10 m	common
P. promelas	speleophil nest spawner guarder	spring summer	15.6	lakes, rivers weedy shallows	mud - creeks streams, ponds	low
Rhinichthys atratulus	lithophil open substratum non-guarder	spring	21.1	streams - riffle areas	gravel - streams	low
R. cataractae	lithophil open substratum non-guarder	late spring early summer	11.7	streams - riffle areas	gravel, sand - streams, lakes <10 m	low

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
Cyprinus carpio	phytophil open substratum non-guarder	spring early summer	17.0-28.0	weedy areas lakes, rivers	mud - rivers lakes <10 m	abundant
Carassius auratus	phytophil open substratum non-guarder	spring		weedy shallows lakes, marsh rivers		abundant
C. carpio x C. auratus	phytophil open substratum non-guarder					abundant
Semotilus atromaculatus	lithophil brood hider non-guarder	spring	12.8	streams - above, below riffles		
Carpiodes cyprinus	Psammophil open substratum non guarder	early spring		streams, flooded areas of lakes	sandy rivers, lakes <10 m	rare
Catostomus commersoni	lithophil open substratum non guarder	late spring	10.0	streams - shallow	sand, mud, weeds, rivers, lakes <10 m	common (abundant 1860-80's)
Moxostoma macrolepidotum	lithophil open substratum non guarder	spring	11.1	small rivers, streams - riffles	rivers, lakes <10 m	low
Ictalurus nebulosus	speleophil nest spawner guarder	late spring summer	21.1	lakes, bays - shores, creek mouths	sand, mud, weeds streams, rivers, ponds lakes <10 m	low (abundant 1800's)

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
I. punctatus	speleophil nest spawner guarder	late spring early summer	23.9-29.5	lakes or rivers	rock, gravel, sand, large rivers, lakes <10 m	low (abundant 1800's)
Noturus flavus	speleophil nest spawner guarder	summer	27.8	streams, lakes, shallow	rock, gravel, sand, mud, streams, rivers, lakes <10 m	rare
N. gyrinus	speleophil nest spawner guarder	late spring - summer		rivers, lakes - shallows	gravel, mud, weeds streams, lakes <10 m	rare
Anguilla rostrata	pelagophil open substratum non-guarder	fall	17.0	Sargasso Sea	muddy, silty lake bottoms	extirpated? (abundant 1860-70's)
Fundulus diaphanus	phytophil open substratum non-guarder	Spring	23.0	streams - weedy pools	gravel, sand, weeds, large rivers, ponds, lakes <10 m	extirpated?
Lota lota	lithopelagophil open substratum non-guarder	winter	0.6-1.7	bays, lakes - shallow	pelagic, streams, lakes >10 m	rare (abundant 1860's)
Labidesthes sicculus	Phyto-lithophil open substratum non-guarder	spring - early summer		streams, lakes weedy shallows	lakes <10 m	low
Culaea inconstans	adriadnophil nest spawner guarder	spring - early summer	8.0	lakes, rivers - shallows	weedy, streams ponds, lakes <10 m	rare

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
Gasterosteus aculeatus	adriadnophil nest spawner guarder	late spring early summer		lakes, rivers - shallows	lakes <10 m	rare
Percopsis omiscomaycus	lithophil open substratum non-guarder	early spring		streams, lakes, shallows		
Morone americana	phyto-lithophil open substratum non-guarder	spring	11.0-15.0	lakes - shallow	pelagic, lakes <10 m	abundant
M. chrysops	phyto-lithophil open substratum non-guarder	spring	14.4-21.1	river mouth - shoals	pelagic, lakes, all depths	common
M. saxatilus	lithopelagophil open substratum non-guarder	spring		rivers	open, rocky shores - lakes rivers	extirpated (seen in 1881)
Ambloplites rupestris	lithophil nest spawner guarder	late spring early summer	15.6-21.1	lakes, rivers, swamps - shallow	rock, gravel, weeds, streams, lake <10 m	rare (common 1890's)
Lepomis gibbosus	polyphil nest spawner guarder	late spring early summer	20.0-27.0	ponds, lakes, streams - shallows	weedy, streams ponds, lakes <10 m	common (abundant 1870's)

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
L. macrochirus	lithophil nest spawner guarder	late spring - summer	-24.5	lakes, rivers - shallows	weedy, streams, rivers, ponds lakes <10 m	common (abundant 1870's)
Pomoxis annularis	phytophil substratum chooser guarder	late spring early summer	14.0-23.0	lakes, rivers - shallows	mud, weeds, streams, large rivers, lakes <10 m	low
P. nigromaculatus	phytophil nest spawner guarder	late spring early summer	19.0	lakes, rivers - shallows	sand, mud, weed, streams, large rivers, ponds, lakes <10 m	low (common 1890's)
Micropterus dolomieui	lithophil nest spawner guarder	spring early summer	16.1-18.3	lakes, rivers - shallows	rock, gravel, sand, rivers lakes <10 m	common (abundant 1850's-1860's)
M. salmoides	phytophil nest spawner guarder	late spring mid-summer	16.7-18.3	quiet bays - shallow, weedy	mud, weeds, ponds, lakes <10 m	rare (1850-1860's)
Perca flavescens	phytophil open substratum non-guarder	spring	8.9-12.2	lakes, rivers - shallows	sand, mud, weeds, large rivers, ponds lakes <10 m	common (abundant 1860's)
Stizostedion vitreum	lithophil open substratum non-guarder	spring	6.7- 8.9	lakes - shoals rivers - fast water	gravel, weed, rivers, lake <10 m	rare (abundant 1860's)

Table 5. (continued)

Scientific name	Reproductive[1] guild	Spawning[2] season	Spawning[2] temp.(°C)	Spawning[3] location	Adult summer[4] habitat	Present[5] abundance
S. vitreum glaucum	lithophil open substratum non-guarder					extirpated? (abundant 1860's)
S. canadense	lithophil open substratum non-guarder	spring	3.9-6.1	lakes, rivers - shoals	lakes <10 m	extirpated? (abundant 1860's)
Percina caprodes	psammophil open substratum non-guarder	late spring		lakes - sandy shoals	rock, gravel, large rivers, lakes <10 m	low
Etheostoma nigrum	Phytophil open substratum non-guarder	spring		lakes, rivers - shallows	gravel, sand, streams, lakes <10 m	low
E. microperca	speleophil nest spawner guarder	spring		lakes - shallow weedy areas	sand, mud, creeks, streams, lakes <10 m	low
Aplodinotus grunniens	pelagophil open substratum non-guarder	early summer		bays, lower rivers, open lake	pelagic, sand, mud, streams, large rivers lakes <10 m	rare (abundant 1890's)
Cottus cognatus	speleophil nest spawner guarder	spring	5.0	lakes, streams - stony shallows	large rivers, lakes >10 m	rare

[1]from Balon (1975); [2]from Scott and Crossman (1973), Christie (1982); [3]from Scott and Crossman (1973)
[4]from Christie (1982); [5]from Whillans (1977).

7. FEASIBILITY OF REHABILITATION

7.1 CONSTRAINTS ON THE FISH COMMUNITY

The success of "... various fish taxa in rivers and lakes within the 'normal' spectrum of such habitats" is governed by the availability of oxygen and protection against predators (Balon 1975; Balon et al. 1977). As lake fertility increases lithophils are replaced by phytolithophils and eventually phytophils. Less specialized, open substrate spawning, non-guarding species give way to specialized guarders and nest spawners (Balon et al. 1977).

There is evidence of "reproductive guild" succession in the harbour. The dominant lithophil and lithopelagophil guilds (salmonines and coregonines) have been replaced by phytolithophils (i.e. alewife) and phytophils (i.e. carp) (see Table 5). The non-guarding behaviour and the requirement of clean rocks and gravel to ensure adequate water flow and oxygen to the eggs strictly limits salmonines and coregonines to a distinctive environment and community structure (Balon et al. 1977). Consequently they are susceptible to organic and contaminant inputs which may affect the oxygen regime. Phytolithophils and phytophils have adaptations which allow them to utilize a low oxygen environment. Hence species in these guilds are the dominant taxa in the harbour presently.

Normally nest spawning species such as smallmouth and largemouth bass might be expected to dominate the taxa in an environment with decreasing but not exceedingly low oxygen content. The adaptation of guarding ensures adequate oxygen and protection from predators for the eggs (Balon et al.

1977). In the harbour, limited habitat and exceedingly low oxygen have prevented this from occurring. The latter appears more limiting at present because the major habitat losses occurred before the 1930's, thus preceeding the decline in the littoral fishery in later years. However, there can be no doubt that species preferring rocky or sandy littoral habitat are limited within the harbour.

This paradigm presents a simplified view of the changes in the dominant fish taxa in the harbour. It shows that poor water quality and lack of suitable habitat are the two major constraints of the fish community at present.

7.2 IMPACT OF REHABILITATION

Historically, Hamilton Harbour was one of the best spawning, nursery and feeding habitats for C. artedii and C. clupeaformis in the Great Lakes. It supported large permanent populations and enormous seasonal immigrations from western Lake Ontario. Given this situation it is conceivable that rehabilitating the harbour probably would contribute to a revitalized herring and whitefish fishery in western Lake Ontario.

The effect(s) of re-establishing S. namaycush is uncertain. Although there is no evidence of spawning in the harbour, there was a small population of permanent residents historically. In addition it is not known if the lake trout in the harbour comprised a separate population or were part of a larger western Lake Ontario population. Thus it is not clear that re-establishing S. namaycush in the harbour would have any direct impact on

the fishery in western Lake Ontario. However, providing spawning shoals in western Lake Ontario, which lake trout in the harbour historically used, would probably be beneficial to lake trout in Lake Ontario.

Fisheries rehabilitation is generally undertaken to provide sport fishing, commercial fishing or some combination of the two. Therefore the level of exploitation will have a direct impact on the success of rehabilitation.

Whitefish were caught only by commerical fishermen in the past and more recently although in some lakes such as Lake Simcoe, whitefish have been the basis of a major winter sport fishery (MacCrimmon and Skobe 1970). It is the most valuable commercial freshwater fish in Canada at present (Scott and Crossman 1973). The popularity of ice fishing in the past suggests that a large sport fishery could develop in the harbour if whitefish were re-established. In western Lake Ontario whitefish would probably come under heavy commercial pressure.

There is little doubt that lake trout would be subjected to heavy sport fishing if re-established in the harbour. This fishing pressure would probably be lessened by increased populations of smallmouth bass, pike and other desirable species in the harbour and Cootes Paradise. Martin and Fry (1973) noted that the introduction of smallmouth bass to Lake Opeongo provided a second sport fishery and served at times to buffer the fishing pressure on the lake trout. In western Lake Ontario lake trout would probably be subjected to heavy pressure from both sport and commercial

fishing. Conflicts will no doubt develop between these two interests. Therefore strict enforcement of fishing regulations will be necessary.

Herring, in contrast to the other species, would probably be subjected mainly to commercial fishing pressure.

Warmwater fish species are generally subjected to more intense sport fishing rather than commercial fishing. One of the major constraints of (and reasons for) rehabilitating warmwater species, besides the lack of habitat quantity and quality, is the high probability of a size selective sport fishery developing. If this did occur it would seriously hamper efforts to maintain increased populations in the harbour and Cootes Paradise.

Historically only small quantities of lake trout, herring and whitefish were caught in the harbour commercially because of a restriction on nets. If these species are successfully re-established a ban on commercial operations would probably be desirable, although high shipping traffic might have the same effect. A large increase in sport fishing would probably occur as a result of a ban on commercial fishing. The location of these activities might interfere with shipping. Consequently it would probably be necessary to limit sport fishing to the northern and western areas where there is little likelihood of any interference.

It is clear from the available evidence that even in the absence of exploitation, fisheries rehabilitation particularly for coldwater species, will not be successful unless water quality improves dramatically.

The problems that need to be overcome in order to successfully rehabilitate the harbour fisheries are twofold. First, the low levels of dissolved oxygen in the deep waters limits their availability to cold water species. It is clear these waters will have to be oxygenated if coldwater species are to survive in the harbour. Unfortunately the methods are not so clear. There is good evidence indicating that artificial aeration will break down thermal stratification warming the deeper waters (MOE 1977; 1978). This may make it unsuitable for coldwater species. Second, the quantity and quality of warmwater habitat is lacking in the harbour. This limits the abundance of warmwater species. Water quality is less of a problem for these fish than the coldwater species although an improvement would probably be beneficial.

Re-establishing naturally reproducing stocks of native species in the harbour is consistent with the objectives of the Strategic Planning for Ontario Fisheries (SPOF) document developed by the federal and provincial governments (Loftus et al. 1978). This document also notes that the stocking of exotic species is temporary. This implies that the Pacific salmon are stocked to provide immediate angling opportunities (Bridger and Oster 1981) and to relieve the angling pressure on native species while attempts are made to re-establish them. There is now a large sport fishery in western Lake Ontario based on stocked Pacific salmon. Two things are uncertain:

1. the ability of lake trout and other native species to sustain the same angling pressure; and,
2. the political acceptability of reduced salmon stocking if and when native species are re-established.

7.3 REHABILITATION POTENTIAL

Table 6 summarizes the rehabilitation potential of the harbour on the basis of the remaining habitat quantity and quality and water quality. Only one area - the south shore around the steel mills - is rated as having no rehabilitation potential. Cootes Paradise and the northwest corner of the harbour are both rated as having excellent potential. The remaining areas fall in between these ratings.

The south shore was given the lowest rating because there is no habitat left in the area and little likelihood that any could be provided. In addition, water quality is so impaired it is doubtful whether anything can be done to improve it. In 1964-65 2 km^2 of sediments around the steel mills did not support any benthic invertebrate community. This area had increased by 1972-73 and may have in part prompted Acres (1973) to conclude that this area was incapable of supporting biological activity.

The two areas which rated the highest potential have the most habitat at present. These areas are extensively utilized by smallmouth bass, pike, yellow perch and carp. Increasing the quantity of habitat and improving the quality of habitat is probably all that is necessary in the way of rehabilitation. Prince and Maughan (1978) have found that artificial reefs increased centrachids such as largemouth and smallmouth bass, various ictalurids, and percids such as walleye. These structures may be useful in Hamilton Harbour particularly along the north shore. Carp control in the littoral habitat will probably have to be undertaken in order to maintain improved habitat quality. Improved water quality is desirable as well.

Table 6. Rehabilitation potential based on the available habitat in Hamilton Harbour

Area	Historically	Presently	Rehabilitation Potential
Northwest corner	marsh and shallow water - coarse and fine sand substrate good spawning and nursery area	some marsh left - substrate mostly mud	Moderate
North shore	sandy, coarse gravel substrate, isolated marshes at mouths of numerous streams - some spawning and nursery habitat	substrate mostly mud some marsh left	Moderate
West and north of Carroll's Point	sandy substrate extensive marsh area excellent spawning and nursery habitat good adult habitat	mostly mud and original substrate marsh area still extensive	Excellent; sediment input from Grindstone Cr. is a problem
Cootes Paradise	extensive marsh area excellent spawning and nursery area excellent adult habitat	marsh extensive although much reduced from historic times still excellent spawning, nursery and adult habitat	excellent; presence of large numbers of spawning carp and influx of sediments from tributaries and sewers are problems
South shore	heavily indented shoreline extensive marsh coarse sand bottom gravel shoals 500 yds offshore excellent spawning nursery and adult habitat	all marsh area has been lost due to landfilling and dredge disposal substrate mostly marsh	none

Table 6. (continued)

Area	Historically	Presently	Rehabilitation Potential
Windermere Basin	extensive marsh area excellent spawning, nursery and adult habitat	small areas of marsh left substrate mostly mud	low
Open water	coarse sand bottom gravel shoals along north and south shore deep waters well oxygenated	mud bottom deep waters become anoxic gravel shoals disappeared	moderate contaminated sediments and anoxia are problems
Hamilton Beach N and S of the Ship Canal	south of canal gravel and sand north of canal fine and coarse sand small marsh area directly south of canal	two areas of coarse and fine sand adjacent to northern half of beach rest of bottom is mud south of canal is dredge disposal area	low

Of the remaining areas, the open water (pelagic and profundal habitats) probably have only moderate rehabilitation potential. This stems not from an actual loss in habitat as in the nearshore areas but from the restricted availability at present. The thermal regime in these waters probably has not changed much over the years. This is essential if cold water species are desired in the harbour. It is not certain at present how water quality could be improved in the open water.

7.4 SUMMARY AND CONCLUSIONS

The major objective of this review was to assess the feasibility of a rehabilitated fishery in Hamilton Harbour. On the basis of current evidence the assessment is positive. As long as water quality continues to improve there is every reason to believe that rehabilitation is feasible. There is still habitat for coldwater species although it will be an immense challenge to make it available to them. The warmwater species are in a much better position. The use of habitat improvement and habitat creating techniques should substantially increase warmwater populations.

A major challenge posed by rehabilitation is the creation of an appropriate institutional framework. New understanding, integration and cooperation are needed to ensure the perpetuation of a viable, diverse and self-sustaining fishery and other desirable uses of the harbour. Such conclusions are not unique to Hamilton Harbour. Francis et al. (1979) made similar conclusions with respect to Great Lakes rehabilitation in general; Regier et al. (1980) implicitly if not explicitly arrived at similar conslusions at Long Point, Lake Erie, and Harris et al. (1982) did the same at Green Bay, Lake Michigan.

A large segment of the public (scientists included) have neglected the Hamilton Harbour fishery for many years because of its highly visible pollution problems. This review shows that on the whole the rehabilitation potential in the harbour is greater than what is generally perceived. Perhaps it will contribute towards active efforts to rehabilitate Hamilton Harbour.

8. INFORMATION GAPS

This review focussed principally on harvesting, deteriorating water quality and physical removal of habitat and their impacts on the fish community in Hamilton Harbour. Broadly speaking this covers nine of the eighteen categories of human stresses on Great Lakes ecosystems identified by Francis et al. (1979). Diversions and consumptive uses of water can be added to the list (Int. Great Lakes Div. and Cons. Uses Study Board 1981). In my M.Sc. thesis (JAH; expected in 1985) I am planning to make a detailed examination of the relevant stresses in the harbour, their sources, and the feasibility of rehabilitation.

During the course of researching and writing this review other information gaps were identified. They are:

1. An analysis of the changes in wetlands is desirable because of their importance in the ecosystem. I am planning to do this in my M.Sc. thesis using aerial photographs and Landsat data.

2. An analysis of the benthic invertebrate community in sediment cores should be undertaken. Benthic invertebrates reflect their physical and chemical environment (Cook 1976) and integrate past and present conditions. Changes in the benthic community might provide a more precise indication of degradative events in the harbour. These could then be correlated with changes in the fish community.

3. There is no recent information on the major tributaries (i.e. water quality parameters, benthic invertebrates, fish, etc.). The only available information is a 1960 report on Spencer Creek (Ont. Dept. Comm. Devel. 1960) and a partial survey of Redhill Creek in 1968 (Ont. Dept. Energy and Res. Man. 1968). Conditions have probably changed since then. It would be useful to document present conditions. The streams could have an important role in rehabilitation of the harbour especially if a coldwater fishery is the goal. If time permits I will survey the major tributaries and report the results in my M.Sc. thesis.

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Appendix I. Seasonal use of Hamilton Harbour by adult fish. Not all of these species can be found in the harbour at present

Taxon	J	F	M	A	M	J	J	A	S	O	N	D
Petromyzon marinus	...	...	...	...	...	___	...	...	...	...	...	...
Acipenser fulvescens	___	___	___	___	___	___	___	___	___	___	___	___
Lepisosteus osseus	___	___	___	___	___	___	___	___	___	___	___	___
Amia calva	___	___	___	___	___	___	___	___	___	___	___	___
Alosa pseudoharengus	___	___	___	___	___	___	___	___	___	___	___	___
Dorosoma cepedianum	___	___	___	___	___	___	___	___	___	___	___	___
Coregonus sp. (deepwater ciscoes)	...	...	...	...	...	...	...	...	...	...	...	...
C. artedii						___	F				S	
	___	___	___	___	___	___	___	___	___	___	___	___
C. clupeaformis						___	F				S	
	___	___	___	___	___	___	___	___	___	___	___	___
Oncorhynchus kisutch	---	---	---	---	---	---	---	---	---	---	---	--[a]
Salmo gairdneri	---	---	---	---	---	---	---	---	---	---	---	--[a]
S. salar										___	___	
Salvelinus fontinalis	---	---	---	---	---	---	---	---	---	---	---	---
S. namaycush										.....[c]		
	___	___	___	___	___	___	___	___	___	___	___	___
Osmerus mordax				___	___	___						
Hiodon tergisus	...	...	...	...	...	...	...	...	...	...	...	...
Umbra limi	___	___	___	___	___	___	___	___	___	___	___	___
Esox lucius	___	___	___	___	___	___	___	___	___	___	___	___
E. masquinongy	___	___	___	___	___	___	___	___	___	___	___	___
Cyprinidae[b]	___	___	___	___	___	___	___	___	___	___	___	___
Cyprinus carpio	___	___	___	___	___	___	___	___	___	___	___	___

Appendix I (continued)

Taxon	J	F	M	A	M	J	J	A	S	O	N	D
Catostomus commersoni	___	___	___	___	___	___	___	___	___	___	___	___
Ictalurus nebulosus	___	___	___	___	___	___	___	___	___	___	___	___
I. punctatus	___	___	___	___	___	___	___	___	___	___	___	___
Anguilla rostrata	___	___	___	___	___	___	___	___	___	___	___	___
Lota lota	---	---	---	---	---	---	---	---	---	---	---	--a
Percopsis omiscomaycus	___	___	___	___	___	___	___	___	___	___	___	___
Morone americana	___	___	___	___	___	___	___	___	___	___	___	___
M. chrysops	___	___	___	___	___	___	___	___	___	___	___	___
M. saxatilus	---	---	---	---	---	---	---	---	---	---	---	--a
Ambloplites rupestris	___	___	___	___	___	___	___	___	___	___	___	___
Lepomis sp.	___	___	___	___	___	___	___	___	___	___	___	___
Pomoxis sp.	___	___	___	___	___	___	___	___	___	___	___	___
Micropterus dolomieui	___	___	___	___	___	___	___	___	___	___	___	___
M. salmoides	___	___	___	___	___	___	___	___	___	___	___	___
Perca flavescens	___	___	___	___	___	___	___	___	___	___	___	___
Stizostedion vitreum	___	___	___	___	___	___	___	___	___	___	___	___
S. canadense	___	___	___	___	___	___	___	___	___	___	___	___
Aplodinotus grunniens	___	___	___	___	___	___	___	___	___	___	___	___
Cottus cognatus	___	___	___	___	___	___	___	___	___	___	___	___

a - occasional sightings
b - see Table 5 for species
c - may be spawning migration out of the harbour
S - spawning migration into harbour
F - feeding migration into harbour
____ definitely present
.... insufficient information - may be present

APPENDIX II Sources for Figures 16 to 23

Historic Distribution

Fig. 16: Kerr and Kerr (Nov. 11, 1876), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 17: Kerr and Kerr (Sept. 5, 1868), (July 4, 1874), (Sept. 9, 1876), (Mar. 7, 1881), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 18: Kerr and Kerr (Jan. 13&28, 1865), (Feb. 3&13, 1865), (Nov. 21, 28&29, 1865), (March 29, 1866), (June 9, 1866), (Sept. 5, 1868), (Nov. 27, 1868), (Nov. 29, 1869), (Nov. 25, 1870), (April 13, 1871), (July 26, 1873), (Feb. 1, 1874), (Nov. 7, 1874), (Nov. 26, 1883), Hamilton Spectator (Feb. 18, 1884), (Feb. 6, 1888), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 19: Kerr and Kerr (Jan. 25&28, 1865), (Feb. 1, 1865), (Oct. 14, 1865), (March 3, 1866), (April 14, 1866), (May 18, 1866), (June 9, 1866), (May 10, 1867), (Sept. 5, 1868), (April 26, 1869), (June 10, 1869), (June 4, 1870), (April 13, 1871), (Aug. 2, 1871), (April 16, 1873), (Feb. 1, 1874), (Feb. 26, 1883), (April 20, 1886), Hamilton Spectator (Feb. 18, 1884), (Feb. 6, 1888), Ham. Fed. Env. Groups (1972), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 20: Kerr and Kerr (Jan. 30, 1865), (Feb. 27, 1865), (June 10, 1865), (Oct. 14, 1865), (March 3&18, 1866), (June 9, 1866), (March 3, 1868), (Sept. 5, 1868), (April 18&19, 1870), (May 8, 1870), (June 4, 1870), (April 13, 1871), (March 7, 1876), (March 12, 1877), (Feb. 5, 1885), (Jan. 9, 1891), Hamilton Herald (Jan. 29, 1892), Hamilton Spectator (Feb. 18, 1884), (Aug. 17, 1886), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 21: Kerr and Kerr (Feb. 6, 1868), (Sept. 5, 1868), (May 15, 1869), (April 13, 1871), (Feb. 1, 1874), (Nov. 11, 1876), (Aug. 29, 1879), Halerow (1970), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 22: Kerr and Kerr (June 10, 1865), (Oct. 13, 1865), (May 19, 1866), (Mar. 8, 1867), (May 10, 1867), (April 4, 1868), (Sept. 5, 1868), (April 29, 1870), (April 16, 1873), (Feb. 15, 1883), (May 10, 1886), Scott and Crossman (1973), Whillans (1977), Christie (1982).

Fig. 23: Whillans (1977).

Present Distribution

Figs. 16-23: Turner (1948), Warren (1950), Ont. Min. Nat. Res. (1975, 1976), Royal Botanical Gardens (1978), Scott and Crossman (1973), Whillans (1977), Christie (1982), Simser (1982).

POOR

QUALITY

ORIGINAL